The Double Dividend

Revenue neutral environmental tax reform and income distribution

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Declaration:

I declare that this thesis is the result of my own research and composition.

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"If you try to sit, I'll tax your seat
If you get too cold, I'll tax the heat"

(Harrison 1965, Northern Songs Ltd.)

Abstract

The concept of revenue neutral environmental tax reform has been around since the early 1970's when the concept of taxing an economic 'bad', e.g., pollution, and using the revenue raised to reduce distortionary taxation was postulated by Sandmo (1973). The basic premise is that such tax reform has a two-fold benefit - a double dividend. The first dividend comes from the impact of the environmental tax on the externality in question and the second divided arises from the beneficial efficiency effect on the tax system resultant from the fall in the level of distortionary taxation. Although a large literature on this issue has built up on this issue in recent years, there has been a significant omission in that the distributional implications of such tax reform have been neglected. The purpose of this thesis is to investigate the consequences, of raising the tax rate on an economic bad and using the revenue gained to reduce the tax rate on an economic good, on the distribution of income. The methodology employed is a progression from a simple theoretical model to a complex computable general equilibrium framework.

Preface

The concept of revenue neutral environmental tax reform has been around since the early 1970's when the concept of taxing an economic 'bad', e.g., pollution, and using the revenue raised to reduce distortionary taxation was postulated by Sandmo (1973). The basic premise is that such tax reform has a two-fold benefit - a double dividend. The first dividend comes from the impact of the environmental tax on the externality in question and the second divided arises from the beneficial efficiency effect on the tax system resultant from the fall in the level of distortionary taxation.

The double-dividend concept remained a minor issue until the 1990's when Pearce (1991) suggested that it was central to the imposition of carbon taxation in the context of global warming. In the years that followed a large literature arose, both theoretical and empirical, that examined the double-dividend in a variety, of frankly confusing, ways. This literature is divided academically between theoretical models that deal with a general, unspecified pollutant and empirical models which deal, in virtually all cases, with carbon or energy taxation. The general consensus of this literature is best thought as being that the double dividend probably does not exist, but that revenue-neutral tax reform may be preferable to the retention of revenue or lump-sum transfer. The foucs here will follow that of the literature - the theoretical analysis will deal with a general pollutant whilst the empirical models will concern themselves with energy taxation. This is for technical reasons - it is difficult to analyse specific pollutants theoretically - as well as to tie in this work with that which is already available.

What is immediately noticeable about the double dividend literature, which is comprehensively examined in Chapter 1, is that with one notable exception (Proost and van Regemorter 1995), it does not examine the distributional implications of such a revenue neutral tax reform. It is the contention here that such distributional effects are central to the issue, especially if one is appraoching it from a political economy perspective. The key goal of this work is to attempt to cast light on how the imposition of such a shift in the burden of taxation will impact on different sections of society.

The basic contention is that lower income groups spend proportionally more of their income on energy and, as such, a shift in the tax buden will, by it's very nature be regressive. Lower income groups will face a proportionally higher loss, or potentially lower gain. If this is indeed the case, it may well mean that the use of such environmental tax reform will be politically, and perhaps socially, unacceptable. It is thus an area that requires investigation.

Three methodologies are used, each increasing in complexity. Chapter 2 examines the issue theoretically by extending the model of Bovenberg and de Mooij (1994b) to cover multiple households. Chapter 3, based on Schöb (1995) is a simple empirical model, dealing with the household sector only. The remaining three chapters use a computable general equilibrium framework. Chapter 4 lays out the theoretical basis of the general equilibrium model, Chapter 5 deals with the issue of calibration and sensitivity analysis and Chapter 6 presents some results. Finally Chapter 7 contains conclusions, both from a methodological point of view, and, in terms of the results acquired.

Chapter 1 - Introduction and the existing double dividend literature

The purpose of this first chapter[1] is to attempt to clarify the concept of the double dividend that may exist from revenue-neutral tax reform, to investigate the large existing literature in the area and to examine the methodologies that may be used in analysis. The focus is on the double dividend literature as a whole, rather than on the specifics of distributional issues as, as will be seen, only a tiny portion of the literature actively considers distributional effects.

1.1. Introduction

Since the 1960s, a central idea of environmental economics has been that it is statically and dynamically more efficient to use taxes or tradable permits, rather than regulation, to control pollution. In the 1970's and 1980's the further proposal was made (Sandmo 1975, Terkla 1984, Lee and Misiolek 1986) that the benefits of such economic instruments of control extend beyond the polluting industry. If the revenue raised by the instruments is used to lower conventional, distortionary taxes such as income tax or VAT, then it is argued that there will be, what has come in the 1990s to be known as, a 'double dividend'. Not only will there be a benefit from lower emissions of the pollutant (the first or environmental dividend), but there will also be a benefit (the second dividend) from reaching a less distorting tax system, following Tullock's (1967) idea of "excess benefit". The overall argument is that emission taxes or tradable permits are more desirable, taking this effect into consideration, than would be calculated if their revenue effects are ignored.

The double dividend idea has been subject to vigorous technical debate, and definitions and analyses (and more than a few measurements) of one or both dividends have multiplied. Goulder (1995b) performed the valuable service of clearing up the semantic confusions that had arisen. In particular, he clarifies the notion of applying 'weak' and 'strong' labels to avoid the ambiguity of some double dividend concepts. However, a gulf still remains among the approaches to the issue. Empirical analysis almost always considers the use of carbon taxes to reduce CO_2 emissions and hence global warming. They thus build, consciously or not, on the origin of the double dividend term (if not the basic idea), and its rooting in a specific policy context:

> "There are major advantages of a carbon tax over the general alternative of regulating [CO_2] emissions through conventional command and control policies. ... A carbon tax....would inevitably be revenue raising... Governments may then adopt a fiscally neutral stance on the carbon tax, using revenues to finance reductions in incentive-distorting taxes such as income tax, or corporation tax. This `double dividend' feature of a [CO_2] pollution tax is of critical importance in the political debate about the means of securing a 'carbon convention'."
> (Pearce 1991)

An extension of this approach, which has found its way into the manifestos of several European political parties, is that of "ecological tax reform" (after von Weizsacker 1991). This applies Pearce's argument from CO2 to pollution in general, and proposes a major shift in the tax system towards taxing "bads" rather than "goods". It perhaps explains why the third approach, that of mainstream economic theorists (especially Bovenberg with de Mooij or van der Ploeg), deals almost always with a general, unspecified pollutant. The focus here is on energy (carbon) taxation but it is important to consider all possibilities.

A point that has been largely neglected, in that some authors may mention it (Bovenberg 1997) but with a few notable exceptions none have analysed it, is that environmental tax reform will have an impact on the distribution of income. It is the purpose of this thesis to examine both the ways this issue can be examined and the issue itself.

From a policy makers perspective the most useful classification for the double dividend literature is by policy move[2] (Section 1.4) but from an academic perspective it may be better to classify it first by academic criteria, between what can broadly be classed the theoretical and empirical literatures (Section 1.3). The classification can be practical again, in terms of the revenue-recycling instrument concerned (Section 1.5). Finally the classification can be technical by means of the measure of desirability used by the authors concerned (Section 1.6). Initially however, Section 1.2 of this chapter looks at the definition of the double dividend and considers the main focus of this thesis - a neglected but vital area, that of distributional issues.

1.2. Definition of the double dividend

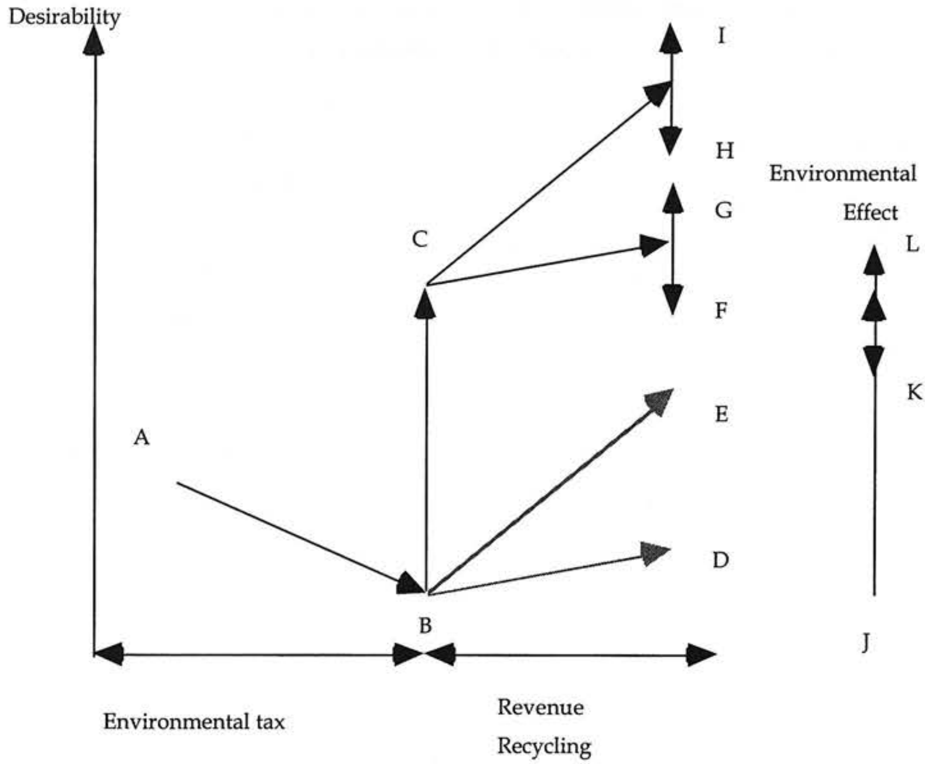
The first part of this section lays out the basic definition of the double dividend. The second part considers distributional issues which may be the most vital part of the double dividend hypothesis in terms of acceptability to policy makers but have been largely neglected, in terms of analysis, in the literature.

1.2.1 The double dividend defined

This section borrows heavily from Goulder (1995b) who provides a comprehensive analysis of the definition of the double dividend. A definition of the double dividend in the context of all possible policy moves (See Section 1.4) can be found in Pezzey and Park (1997).

The double dividend consists of an environmental dividend (the first dividend) and a dividend from an increase in the efficiency of the tax system (the second dividend) and is best explained through the use of a diagram. In Figure 1 the vertical axis represents some notion of desirability (See Section 1.6). Movements along the horizontal axis represent the two stages of revenue-neutral tax reform - the imposition of an environmental tax and the recycling of revenue. Points A and B are intermediate stages in the process, points D and E are for explicate power and points F to I are possible outcomes. In Figure 1 a vertical line (BC, FG and HI) represents a change in the environment and a diagonal line represents a change in the tax system.

Figure 1.1 - Desirability of revenue neutral tax reform.



The process of analysis begins with the move from A to B which is simply the imposition of an environmental tax with the revenue being retained. AB represents this imposition before environmental effects are taken into account. It is however, assumed that this tax change will cause an improvement in the environment, represented by the line BC. Thus the imposition of an environment tax, where the revenue is retained is desirable because of the environmental benefit, but undesirable because of the higher tax burden. It should be remembered however, that the revenue raised does not disappear. The usual analysis is to assume that it is returned in lump-sum fashion[3]. A lump-sum return of revenue is non-distorting and would be represented by a horizontal line on the diagram[4]. Thus the imposition of an environmental tax is represent, in desirability terms, by a move from A to C.

So far nothing can be said about the double dividend hypothesis[5]. However, once the revenue raised by the initial environmental tax is used to reduce other, distortionary taxes, the nature of the second dividend becomes clear.

The effect of the reduction in other taxation is represented by either of the dotted lines, BD and BE and the second dividend by AD and AE. In the case of BD, the loss of desirability caused by the environmental tax (AB) is offset, but not completely, by the reduction of other taxation. This is the weak form of the second dividend and is often referred to as an increase in the efficiency of the *rest* of the tax system. Goulder (1995b) also defines an intermediate second dividend, which specifies that there is at least one redistributive tax for which the strong form of the second dividend holds. It may be argued that this is unnecessary as the double dividend is not defined until the particular revenue recycling instrument is defined. See Section 1.5.

The move to point E, represented by the line AE represents the strong form of the second dividend. In this case the loss of desirability caused by the environmental tax is more than offset by the reduction of other taxation. In other words there has been an increase in the efficiency of the *whole* tax system. This has important policy implications. The existence of the strong form of the second dividend can be seen as the holy grail of environment tax reform as it represents a free (environmental) lunch. With the strong form the magnitude of environmental effects need not be considered, as the switch in the tax system (the move A to E) is desirable in itself. Given the difficulty in quantifying the value of environmental improvements this is a persuasive argument.

The story does not end here however. So far, the second dividend and the environmental effect of the environmental tax have been considered. Schöb (1995) makes the point that the recycling of revenue will also have an environmental effect. Whether this effect is desirable or not will depend on two factors. It is obvious that the tax rate that is reduced will be the primary influence. The effect will depend on the relationship between the item that is subject to less taxation and the environment. It is also obvious, but may be overlooked, that the measure of desirability being used is also vital. Thus, this second environmental effect is indeterminate. The overall environmental effect is represented to the right of the main diagram in figure 1 by a line from J to between K and L[6]. Combining the two dividends we move from A to a point between H and I (the strong form) or between F and G (the weak form).

The rejection of the strong form of the second dividend by much of the literature often seems to be viewed as a reason for the rejection of revenue-neutral environmental tax reform. This view should be tempered by careful consideration. The existence of the weak form of the second dividend is almost universally accepted and is preferable to the case of non-revenue neutrality[7]. This is in addition to the standard benefits of taxation of externalities over other forms of control, in that taxation allows the achievement of a least cost (in terms of abatement costs) solution. This issue is considered in great detail in Pezzey and Park (1997).

1.2.2 Distributional Issues

The area of distributional issues is one that is mentioned by the literature far more often than it is analysed, yet may be the crucial factor in determining the acceptability of revenue-neutral tax reform to policymakers and politicians.

> 'Distributional issues are at the heart of the double dividend issue: Without distributional concerns, taxes would not need to be distortionary as governments could freely use lump-sum taxes to meet their revenue needs.'
>
> Bovenberg (1997)

It is important to make the distinction between distribution in terms of property rights and distribution in terms of equity. With any tax reform there will be a redistribution of welfare. Some will gain, others will lose. However, in the context of the double dividend we are concerned specifically with equity or more strongly, equality, considerations. It is important to realise that by equity we mean some notion of 'fairness' and by equality a more even distribution of income. Equity is desirable and equality may be but is much more subjective. To avoid this issue it is useful to simply ask, will revenue neutral environmental tax reform be regressive?

It would seem to be easy to analyse the problem theoretically. If the tax that is increased on the environmental good is more regressive than the tax that is lowered then the change will, overall be regressive. In this case, lump-sum transfer would be preferable from the point of view of equality. If the situation were reversed the tax reform would be progressive and equality would be increased. This is relatively simple analysis to undertake in terms of environmental tax reform involving indirect taxation. The situation is made much more complicated with the introduction of labour taxes. This brings the question of unemployment into the equation and also the question of which income groups are most at risk, given a specific reform package, from unemployment. It would be possible, in terms of unemployment, for a strong second dividend to leave the poor much worse off, if employment was diverted away from sectors of the economy that those on low incomes are predominately employed.

As mentioned above there has been relatively little work done on the problem. Proost and van Regemorter (1995) find that the double dividend hypothesis can fail completely when distributional effects are taken into account. They use an applied general equilibrium model, for Belgium, that can simulate two macroeconomic regimes - fixed and flexible wages and include estimates of environmental benefits for major air pollutants. With flexible wages, the choice of tax-reform strategy does not effect aggregate economic results but has an impact on income distribution: tax proceeds may be used to increase welfare payments or to decrease direct tax rates. When real wages are fixed, Proost and van Regemorter find that the gross costs of a carbon tax are high and that reducing social security payments for employers (Employer's National Insurance contributions in the UK) is the optimum way of returning tax revenue.

1.3. The academic debate - Theory versus Empiricism

A distinction between those authors who tackle the double dividend question in a theoretical manner and those who consider it empirically is the most obvious way to classify the literature from an academic point of view. This distinction must be remembered whenever the double dividend is discussed. The reason for the importance of this academic distinction is that, simplistically, the theoretical literature tends to reject the strong form of the double dividend, whilst the conclusions of the empirical literature are more mixed. The reasons for this distinction are not immediately apparent but some possible explanations will be suggested.

The key theoretical result is that of Boveberg and de Mooij (1993, 1994b). A detailed analysis can be found in Goulder (1995b), and Boveberg and de Mooij (1994b) forms the basis of Chapter 2, so only a brief outline is given here. The basic idea is that the imposition of the environmental tax is successful in reducing emissions. The problem arises from the fact that this success causes an the erosion of the environmental tax base and a loss of revenue. This loss of revenue results in an inability to reduce other taxes enough to compensate for the adverse effects of the higher pollution tax, from a consumption viewpoint. In addition, substitution between inputs, caused by the environmental tax, means that labour market distortions may actually increase. Thus, real wages and hence employment fall. Welfare effects depend on the separability assumptions between consumption, leisure and environmental quality. Given this analysis however, it is still found that adjustment of distortionary tax rates is preferable to lump-sum transfers. The weak form of the second dividend holds.

On the other hand the empirical literature cannot be so neatly labelled. The results are much more mixed. Authors such as Brinner et. al. (1992) and Goulder (1992 and 1995a) find that the strong form of the hypothesis fails but many other authors, among them Capros et. al. (1996) and Bossier and De Rous (1992) find in favour of the strong form.

The papers mentioned above and those examined in a policy context in Section 1.4.2.3 all share the distinction of being general equilibrium models of varying complexity. As such they may be picking up more of what is happening than the theoretical models which by their nature are forced to be more simplistic. However, it may be argued that an important factor could be that the empirical models implicitly consider existing environmental regulation by their use of baseline scenarios for calibration purposes. As will be seen in section 1.4 this issue is important and is generally ignored by theoretical work.

In mitigation, the empirical literature deals with carbon / energy taxation, which is obviously not subject to the regulatory standards, both technical and emission based, set for pollutants such as sulphates etc. However, there are still strong effects that must be considered. The key point is that any current baseline will be in compliance, or at the very least is supposed to be in compliance, with existing regulation. We would suggest that any form of energy-use technical standard will have some bias on the results a model that does not include it, generates. In addition any form of environmental standard, be it for SO_2 or other pollutants, will have some impact on energy usage. Brendemoen et. al. (1996), although they do not explicitly consider the issue, probably analyse this effect most efficiently due to the extensive range of pollutants they include in their model.

This divergence between the theoretical and empirical literature was diminished somewhat by Bovenberg and Goulder (1996). The paper focuses on the how the optimal environmental tax rate differs from the Pigouvian ideal when the existing second-best tax structure is taken in consideration. This analysis is undertaken both theoretically and empirically[8]. Although the double dividend is not explicitly examined the theoretical and empirical results are very similar.

Although the focus of this work is not econometric, there is a body of econometric literature on energy taxation, specifically, and other tax reform, more generally. This literature is considered briefly here and further details can be found in Majocchi (1996). A further comprehensive survey can be found in Clarke et. Al. (1996). Ingham et. al. (1994) provide details of many of the estimates of the levels of carbon taxation required to meet specific targets, both globally and for the UK (and the US) specifically.

Very few econometric studies explicitly consider the double dividend and most focus on the cost of standard forms of carbon taxation. A notable exception is Barker and Gardiner (1996) who use an econometric approach to examine the tax incidence effects of (primarily) employers social security contributions[9] as a revenue recycling instrument. They find, subject to a proviso, namely that the nature of the relationship between unions, employers and governments in terms of wage negotiation is likely to be important, that reductions in employer's payments are likely to lead to lower real wage costs and higher employment. Additionally, as energy intensive and energy producing industries tend to have low labour intensities, revenue neutral environmental tax reform, with employers social security contributions as the recycling instrument is likely to reduce pollution and increase employment. In other words, they find evidence to support the strong form of the double dividend.

The econometric model used by Barker and Gardiner (1996) (E3ME - a general Energy-Environment-Economy Model for Europe) is a multi-sectoral dynamic regional model that was developed from a regional E3 (Energy-Environment-Economy) model for the UK detailed in Barker and Peterson (1987). Barker, Baylis and Madsen (1993) use this earlier model to analyse the effects of a carbon tax on the UK economy.

Barker (1998), extends Barker and Gardiner (1996), again using the E3ME model, and deals with the uncoordinated, co-ordinated and unilateral introduction of energy taxes (excise duties) to reach a 10% reduction of CO2 emissions, which is recycled by a cut in social security contributions. The results show a considerable 'double dividend' effect and a considerable employment effect. The employment effect for the EU lies between 1.2% (co-ordinated) and 1.3% (uncoordinated) showing effects of more than 2% for some countries.

As far as distributional issues are concerned, there has been a small amount of econometric work undertaken. A survey of early work can be found in Bradshaw (1978). This early work was concerned with the variation in fuel expenditure across household types. The household characteristics included income but also composition, dwelling size and type, regional location and central heating. However, this analysis did not go beyond the consideration of the pattern of the relative budget shares for energy across different household types.

Common (1985) considers the distributional impact of higher UK energy prices explicitly and takes into account the impact of higher energy prices on other commodity prices by calculating indices of cost of living changes (consequent on higher energy prices) across all commodity price changes caused by higher energy prices. He finds that ignoring this issue (namely the effect of increased energy prices on other commodity prices) typically understates the total effect by around half[10]. His results are consistant with the claim that higher energy prices are regressive in their impact in the UK though the size of this impact is relatively small - in the region of a 5%

greater effect on the worst affected household group compared with all households generally. However, the data for the simulations is the 1974 input-output tables and so the results should be viewed with some caution, a quarter of a century later.

1.4. Policy move and Pollutant

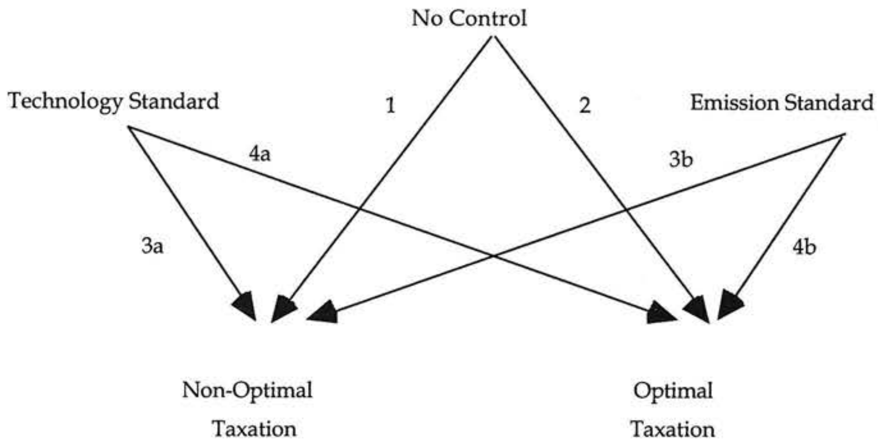
The first part of this section lays out the policy framework in which the double dividend hypothesis should be considered. The second section then considers, in depth, the literature within this policy framework. However, as will be seen, as soon as one starts to consider policy, then the actual pollutant concerned is of vital importance.

1.4.1 A framework for categorisation

There has been a tendency for the academic debate on the double dividend hypothesis to stray from the original policy context. Pezzey and Park (1999) deals with this issue in some detail. It is the intention of this section to lay out the policy framework that the double dividend debate fits into. To this end it is useful to look at the possible ways in which governments can control environmental externalities, that are relevant to the double dividend. The key point is that the most suitable policy will vary with the pollutant in question. In our view, this is an issue that has been neglected in the arguments that have arisen over the double dividend. The focus will be on those moves or shifts in policy that are relevant to the double dividend.

Figure 1.2 shows the possible policies that a government can take to control a pollutant, that are relevant to the double dividend hypothesis. It is however, policy moves that are the focus of interest. More specifically still, it is policy moves that allow a double dividend. A move from the current policy (which we assume does not include market based instruments) to emission taxes is thus required. These taxes may be optimal or non-optimal. The current policy, assuming no market based instruments are currently in use, is likely to be either no control, technology standards or emission standards. This current policy is of crucial importance and is often overlooked in the double dividend literature. Other market instruments such as tradable emission permits are not considered here. Although they are of relevance to the double dividend debate, they are not considered in the literature. Pezzey and Park (1999) considers the double dividend in a wider policy framework, including other market instruments.

Figure 1.2 - Possible policy moves giving rise to the double dividend



Crudely speaking, there are three criteria for any move away from current policy to be first considered and then adopted and the application of these criteria depends on the pollutant in question. Firstly, it must be known that emissions cause environmental damage. The local damage caused by SO_2 has been known for decades, although awareness of its long distance damage via acid deposition is more recent. Confirmation that rising CO_2 concentrations will alter climate significantly has been very recent, and is still controversial.

Secondly, emissions must be controllable. Again the nature of the pollutant is important. In respect to control of emissions, pollutants can be classified into two broad types - those that are a unwanted by-product of a production process and those that are, in some sense, the goal of a production process. The first category, by-products, covers most 'traditional' pollutants such as SO_2, particulates etc. In this case, there must exist an affordable technology to control emissions or in other words it must be possible for producers to clean up after themselves. Technologies to control SO_2 emissions are commercially available, though there has been a long debate about whether the best technology is simply to use tall stacks to disperse and dilute the emissions, or flue gas desulphurisation to reduce total emissions at source[11]. With this type of pollutant, the goal of environmental policy is the introduction of the appropriate control technology.

The second case, the product of a production process being a pollutant, is more complex. The most obvious example is CO_2, from fossil fuels, although in the recent past CFC's also fell into this category. The distinction is that for pollutants in this category there is no control technology and the goal of environmental policy must be to reduce or eliminate the usage of a product. In the case of CFC's, this was achieved, in the developed world at least, by the introduction of non- environmentally damaging alternatives. Unfortunately, in the case of CO_2, no alternatives are immediately available, at least on a sufficiently large scale. So the goal of policy must be to limit, or at least reduce, usage.

Finally, it must be affordable for the government or agency to monitor the results of its policy and there must be the political will to impose the costs of control on polluting firms (and their customers). Leaving aside the issue of political acceptability for the moment, there are big differences in monitoring costs between SO_2 and CO_2, as shown by the following data:

Table 1.1 - Source of total emissions by pollutant type.

Pollutant	Proportion of total emissions coming from:	
	Housing, commerce, transport and agriculture	Power stations, refineries and other industry
SO_2	11%	89%
CO_2	44%	56%
Source: UK. Dept of Trade & Industry (1996), Digest of UK Energy Statistics, pp 190-1.		

The 44% of CO_2 emissions which come from small and often mobile emitters makes it prohibitively expensive to monitor a big enough proportion of individual emissions. In addition, the it is generally difficult if not impossible to increase the energy efficiency of most existing equipment.

All in all it is no surprise that there has been no political will to set standards for existing CO_2 technologies. Technology standards, which are in terms of energy efficiency, for CO_2 therefore apply only to new equipment. We will observe later that the literature pays little explicit attention to such standards.

Even if they are possible, technology standards have obvious disadvantages. They give no incentive to find alternative means of control, and they given no direct control over the level of emissions. It is therefore preferable to have to emission standards[12], provided that the information costs of so doing are reasonable, which is generally true for SO_2 given modern monitoring equipment.

The equivalent, indirect move for CO_2 would be to move from setting standards for new energy equipment, to fixing the amount of carbon-energy actually sold (since CO_2 emissions are directly in proportion to this). This is obviously seriously impractical and incredibly costly. This is the origin of the idea of moving from (indirect) technology standards for CO_2, to control by carbon taxes. This will create a pervasive incentive to reduce CO_2 emissions in the most cost- effective way, without specifying which users are to reduce emissions, by how much or with which technologies. But because monitoring CO_2 emissions directly is so costly, and because almost all carbon fuel used is burnt[13], the tax incentive is applied to carbon inputs instead. Without carbon taxation (which could be implicit, for example the reduction of any existing subsidies for carbon-energy use), many analysts cannot see how widely-agreed targets for CO_2 control can be achieved.

But why is there no equivalent literature on sulphur or SO_2 taxes, extolling the virtues of using the revenue from them to get a double dividend by lowering conventional, distortionary taxes? Indeed, there is virtually no literature solely on SO_2 taxes as such. The nearest one comes is in an empirical discussion of 'Ecological Tax Reform' (von Weizsacker 1992) - i.e. a deliberate, macroeconomically significant move from taxing "goods" such as income, labour and commodities towards taxing "bads" such as pollution, congestion and resource depletion. This is because firstly, SO_2 emission standards are feasible and moderately effective. Secondly, because thanks to much lower monitoring costs, a politically much more attractive alternative is available. Any concern about the inefficiency of emission standards (caused by their typical uniformity, which again is a result of the information costs of non-uniform standards) will therefore push policy in the direction of that alternative, not towards revenue-neutral SO_2 taxes.

Revenue-neutral emission taxes can be set non-optimally. This is virtually inevitable for carbon taxes, given the near- impossibility of valuing environmental damage. To our knowledge only Nordhaus (1991) has attempted the numerous and highly debatable empirical and ethical[14] assumptions needed to calculate an optimal carbon tax. Or, taxes can be set "optimally", which is what the theoretical literature does. As we shall see, this literature universally ignores any pre-existing technology (or emission) standards, and assumes instead that there is no emissions policy to start with. In all these cases, the policy move is not well- defined until the means of revenue-neutrality is specified: that is, which conventional tax is to be reduced using the emission tax revenue. See Section 1.5.

The most important detail is the fact that the no policy situation, in effect, does not exist in reality. In practice, some form of environmental regulation exists for all pollutants, whether it is specifications of nuclear storage facilities or regulations on the design of waste sources. More importantly, there are strong interlinkages between regulatory standards for any pollutant and energy usage. A simplistic example would be the mandatory fitting of catalytic converters on cars, having an effect on their (energy) efficiency. The theoretical analysis of the double dividend question (see Section 3) does not tend to acknowledge the existence of existing regulatory standards, whilst the empirical literature does. In reality it is very likely that all pollutants are subject to both forms of regulatory standard (Technological and emission based) either explicitly or, especially in the case of carbon, implicitly.

1.4.2 The literature within the framework

This section categorises the double dividend literature into the framework outlined in Section 1.4.1. Due to informational difficulties we do not make the distinction between a current policy of technology standards or emission standards but consider them jointly as regulatory control.

1.4.2.1 No control to Non-Optimal Taxes

This category, represented by policy move 1 on Fig. 2, contains for the main part, theoretical papers and one, that of Schöb (1995) that attempts empirical analysis. This paper becomes the basis for Chapter 3. Bonetti and Fitzroy (1996) set up a theoretical model and then produce simulation results, although the model is not calibrated, in the strictest sense to real world data.

The basic result is the standard Bovenberg critique that the erosion of the environmental tax base results in an inability to reduce other taxes enough to compensate for the adverse effects of the higher pollution tax. The strong dividend fails but the weak dividend holds. From a different perspective, Parry (1995), in a very simplistic model, shows that by increasing marginal production costs, environmental taxes reduce GDP and this is not compensated for by a reduction in distortionary tax. A negative exception is Proost and van Regemorter who find that if the macroeconomic regime is one of flexible wages and fixed employment the second dividend fails. This is because with fixed-labour supply and their redistributive instrument, social security contributions, there is no reduction in distortions.

Labandeira-Villot and McCoy (1996) explicitly consider the issue of the first dividend (environmental improvement) depending on public finance considerations, in other words the redistribution of revenue. This is the issue raised in moving from **J** to either **K** or **L** in the right of Figure 1. Schob (1996) also analyses this question, first from a theoretical perspective and then empirically. He uses commodity taxation as the revenue returning instrument and shows that the environmental dividend will depend on the complementarity or substitutability relationship between the polluting good and the revenue returning instrument chosen. He uses a partial equilibrium model of the UK economy, based on Pasardes (1991) Almost Ideal Demand System and finds that the strong form of the second dividend fails. As mentioned above it is this paper, extended to multiple households, that is the basis for Chapter 3.

Bonetti and Fitzroy (1996) show, in contrast to other authors, that a small, revenue-neutral energy tax will raise employment at constant wages if government expenditure is not large. Although the authors interpret their tax energy tax rise as an additional tax rise on fossil fuel energy, the relatively simplistic nature of their model categorises the paper into this section. The simulation results presented show that a substitution of energy taxation for labour taxation, which doubles the price of energy, increases output by 1%, employment by 6-9% and Welfare by 5-13% if the net wage is held constant. To some extent, the result is driven by this assumption in that a constant net wage, given a lower income tax rate, means that gross wages fall and thus labour demand rises. Fitzroy (1996) also finds that there is the possibility of a strong dividend existing. Schneider (1997) shows that where involuntary unemployment exists, a second (employment) dividend may be possible if workers do not respond to lower unemployment by reducing their effort.

Bonetti and Fitzroy (1999) model involuntary unemployment by imposing a constant real wage and using simulation analysis, based on a relatively simple model, find that there are substantial net welfare and employment gains for a plausible set of parameters. This result is driven by the fact that a (relatively) small increase in energy taxation increases the return to (fixed) capital as in the Cobb-Douglas specification used, capital is a fixed proportion of output.

1.4.2.2 No control to Optimal Emission Tax

This category of policy action is by far the most common theoretically and is represented on Figure 2 by policy move 2. It is a shift to optimal taxes that has the most appeal intuitively in that optimal tax rates mean that pollution is optimally controlled or in other words the environment receives the 'right' amount of help. However, there are obvious problems in quantifying optimal rates as the monetary value of the environmental impact of the pollutant is required. We would argue that the very concept of 'optimal' environmental taxation is, for this reason, of little use to policy-makers. This is particularly the case with CO_2 taxation in the context of global warming.

Policy action 2 represents most of the work of Bovenberg and co-authors. An in depth analysis of theoretical methodology is not attempted here. Rather, a few stylised facts are presented. Bovenberg and de Mooij

(1994b, 1993) and Bovenberg and van der Ploeg (1994a, 1994b) all find that the strong form of the double dividend fails, although the weak form holds. Bovenberg and de Mooij's simplistic models of 1993 and 1994b are elaborated on by Bovenberg and van der Ploeg, who include variable labour supply in an open economy (1994b) and a closed economy (1994a).

However, Bovenberg and de Mooij (1994a) find, that when the environmental externality has an impact on production, the strong form may hold if this externality is large. Also, the inclusion of involuntary unemployment in Bovenberg and van der Pleog (1996) suggests more hope for the strong form. They use an analytical general equilibrium model of a closed economy, which also considers the possibility of a third dividend arising through the analysis of the optimal level of public spending and find that this triple dividend is possible. Employment will rise if the shifting of the tax burden of firms away from wages, outweighs the effect of a fall in the marginal cost of public funds encouraging the government to raise the overall tax burden. A welfare 'triple dividend' will occur if environmental concern is small, fixed factors account for a large share of production, substitution between fixed factors and resources is easy and substitution between resources and labour is difficult. This result is qualified by the suggestion that it is more likely in the short-run and unlikely in the context of an open economy with internationally mobile capital.

It will be noted that the inclusion of involuntary unemployment in this paper and that of Bonetti and Fitzroy (1999), above, tends to give more favourable results in terms of the existence of a double-dividend. This is an issue that is returned to in section 4.9.3.

1.4.2.3 Technical Standards to Non-Optimal Taxes

Policy action 3, a move from regulatory standards to non-optimal taxes is the most common policy action empirically. Indeed, the literature, in this context, deals entirely with empirical measures of carbon/energy taxes. The reason for this is two-fold. Firstly, there is the implicit inclusion of regulatory standards, technical in the case of energy[15], when one has reference to a baseline case, a natural process in computable (empirical) general equilibrium modelling, the way in which carbon/energy taxes are most commonly (and usefully) analysed. Secondly, in a general equilibrium setting, the use of non-optimal tax rates is the most natural way to proceed, especially when dealing with carbon / energy. Setting optimum tax rates to control greenhouse gases requires knowledge of the relationship between emissions and concentration of gases in the atmosphere, the relationship between concentration and climate change and not least, the feedback from climate change onto the economy. Including these effects within an economic model is challenging to say the least. It has been attempted - see the DICE (Dynamically Integrated Climate Economy) Model of Nordhaus (1993)[16] - but the simplifying assumptions of the science and the variability of results to these assumptions are large. As such, the validity of the results gained, for policy making, are easily challenged. Thus, the majority of the empirical carbon / energy literature focuses on non-optimal taxes and to a large extent, until climate-economy interactions are understood more fully, this is the most useful approach.

Brendemoen and Vennemo (1996) calculate the effect of the imposition of taxes on eight different pollutants (SO_2, NO_2, CO, CO_2, VOC, CH_4, N_2O, Particulates), that appear primarily through their role as composites of fossil fuels. The authors calculate both a measure of the direct impact of tax changes, the second dividend, and a measure of both the direct effect and environmental impact, the overall dividend. Without including externalities, overall welfare increases when CO_2 tax rates are raised and Income tax or VAT levels are reduced, remains the approximately the same when gasoline and oil are taxed and income tax levels reduced and falls for oil and gasoline taxes with VAT reduction. If externalities are included then all the above tax changes are welfare increasing. Reference should again be made to their implicit inclusion of regulatory standards for a wide range of pollutants.

Capros et. al. (1996) use the GEM-E3 CGE model for the 12 EU member states linked through endogenous trade. They find that Employment increases across the EU with the exception of Greece which loses 12000 jobs. The UK and Germany gain most. They find that GDP at market prices increases by between 3.27% (Belgium) and 1.22% (Greece). However, they make the critical assumption that the real wage elasticity of labour supply is relatively high.

Carraro et. al. model a segmented labour market within a dynamic CGE model of the EU. They consider a carbon tax with the revenue used to reduce payroll taxes, paid by employers[17]. They find that employment rates rise in the short run, but stabilise to the baseline case in the long-run, except in the UK where there is a positive effect in the long run. Brinner et. al. (1992), although they use a less sophisticated methodology and do not explicitly analyse the double dividend, find the strong form exists in the long term, if the revenues raised by a gasoline tax are again used to reduce payroll (employer paid) taxes, in the US. Welsch (1996) finds that the strong dividend will hold, in terms of employment, if there are no increased wage claims.

These papers are in conflict with the studies by Goulder (1995b, 1992) that use a similar sophisticated methodology. Goulder (1995) finds that the impact of a carbon tax on intermediate goods and it's narrow base outweighs the benefit of the attendant labour tax reduction. In his 1992 paper, Goulder finds that although the welfare loss is lower if revenues are redistributed through income tax, corporation tax and payroll taxes, as opposed to a lump-sum fashion, there is still a welfare loss.

In the case of Bossier and De Rous (1992), revenue from carbon taxation is returned in the form of subsidies to investment in energy efficient technology[18]. Unsurprisingly perhaps, their empirical results suggest that this policy, although it reduces GDP in the short term, increases GDP in the long-run. This is due to the fact that energy efficient technology takes time to come 'on-line'. Although the modelling of future technical change is fraught with difficulty the result would seem sensible.

1.5. Choice of revenue-recycling instrument

It is simple to list the available alternatives. Personal income taxes, corporate income taxes, employment taxes, specific commodity taxes, general commodity taxes (whether on sales or value added), and social security contributions are the main ones. The important point is that the choice of revenue returning instrument will, obviously, make a difference to the desirability of revenue neutral tax reform.

The most common choice of instrument is labour or income taxes. It is interesting to note that with the exception of Brendemoen and Vennemo (1996) all papers that consider income taxes find that the strong form of the second dividend fails. The majority of the papers are theoretical so the points made in Section 3 may apply but Brinner et.al. (1992) and Goulder (1992) both find that whilst labour tax reductions do not give a strong second dividend, other tax reductions do. A problem may be that labour taxes are generally not modelled to a sufficient degree of accuracy. For example, most models view income tax as simply a proportion of income. This is a technical necessity in general equilibrium modelling[19]. The reason is that a more realistic income tax structure, including tax allowances and bands is discontinuous and will result in a general equilibrium model behaving unpredictably or not achieving solution.

Both the above papers in addition to Capros et.al. (1996) and Carraro et. al. (1996) find that a reduction in payroll taxes[20] is most likely to provide the strong form. This is perhaps because this is one tax reduction that may benefit both producers and consumers directly. We would argue that the way forward is more comprehensive modelling of realistic tax structures and an examination of all possible redistributive instruments.

1.6. Measurement of desirability

Of fundamental importance to the double dividend hypothesis is how it is measured, or more specifically over what it is measured. Section 2.1 defined the double dividend purely in terms of its desirability. The usual measures of desirability are employment, output and most commonly, welfare. Although an increase in any or all of these would, generally, be considered desirable, for a given policy change an increase in one may not necessarily mean an increase in each or either of the others. It is possible, for example, for output to increase following some change in the tax system but for employment to fall[21]. Although we accept that many authors impose this distinction within their work (Bonetti and Fitzroy (1996), Bovenberg and de Mooij (1993), Bovenberg and van der Pleog (1996), Capros et. al. (1996), Goulder (1992)), we feel that it is important to stress that it should be remembered.

The most common and obvious way to measure desirability is through some notion of welfare, usually measured as the change in some social utility function which depends on both goods consumption and pollution. The exact functional form of this welfare function will have a bearing on results. Using some notion of welfare as a yardstick does have the advantage of being the only measure of desirability that can directly capture environmental effects. However, most of the literature, including this paper, makes the important assumption that the effects of consumption and emissions on desirability are additively separable. In other words the environment is a component of welfare but does not affect any of the other components[22]. But without additive separability, it is hard to agree on how to decompose the desirability effect of introducing a revenue-neutral emissions tax into an environmental dividend and a second dividend from reduced tax distortion.

Another common method of measurement is that of changes in employment (Capros et.al. 1996, Carraro et. al. 1996, Fitzroy 1996 and almost all the papers by Bovenberg and co-authors). In this sense the second dividend is measured in terms of the effect of the revenue-neutral tax change on the labour market and as such the modelling of the labour market becomes crucial. Obviously one must not assume full employment if one wants to measure employment effects. This was illustrated in section 1.4.1.2. by the inclusion of involuntary unemployment in Bovenberg and de Mooij (1996) reversing the results of their earlier models. This should be contrasted with the work of authors, such as Schöb (1996), who ignore labour market effects completely. There are obvious linkages between welfare and employment, but which measure is used can make a big difference to the way a theoretical model is constructed. This makes comparisons between such models much more difficult.

This difficulty in comparison gets worse when one considers empirical models of revenue-neutral emission taxes, which are relevant to double dividend questions, even if the models often do not explicitly recognise this. As mentioned above virtually all such models are of carbon-energy taxation.

The complex nature of general equilibrium models means that a comparison of even two models requires detailed scrutiny. Looking at the empirical literature as a whole, the measures of desirability used vary, and include output and growth in addition to welfare and employment. In this context, the problem of comparison of models is compounded by the problem of comparison of results.

1.7. Conclusions

The literature on the double divided has been considered from several different aspects - policy, academic methodology, method of revenue recycling and desirability. The main point is that the divergence between the theoretical and empirical literature may be due to pollutant non-specific nature of the theoretical literature and its neglect of existing environmental regulation.

Theoretical developments in recent years have been very useful in refining the definition of the strong and weak forms of the double dividend hypothesis. They have shown not only that the strong form of the double dividend hypothesis - that the reduced distortion from using emission tax revenues is larger than their basic cost - is very likely to fail. Furthermore, they have shown that returning emission tax revenue as lower conventional taxes rather than as lump sums may fail to improve welfare, and even fail to lower emissions. But in so doing they have also shown that only empirical measurement can determine these failures will occur in practice. This consensus is qualified somewhat by those papers that model involuntary unemployment as they tend to be more favourably disposed to the existence of the strong form.

Once one looks at the empirical literature on, or accidentally relevant to, the double dividend idea, one rapidly realises how it is entirely restricted to the idea of taxing carbon and/or energy use. This is not surprising, because CO2 is the only major pollutant where the costs of directly monitoring and controlling the large majority of emissions are prohibitive, and therefore directly revenue-neutral alternatives such as grandfathered tradable emission permits have not been considered. The outcome is that wider forms of the double dividend idea, such as the idea of reforming the whole tax system to tax "bads" rather than "goods", are almost entirely untested.

However, empirical results so far seem to suggest that the weak form of the double dividend hypothesis is true, so carbon taxation is indeed more attractive than would be calculated if its revenue effects were ignored. Many studies also find the strong form. What needs to be done is therefore for empirical modelling to ensure that it addresses the subtler, indirect effects of revenue-neutral emission taxes that the theorists have highlighted. It also needs to address the practical and political realities of the pollutants under debate. Modelling taxes on SO2, particulates or BOD effluent will produce very different numbers than for carbon. Attention needs to be paid to the starting point of current policy, to the administrative costs of monitoring, and it would help if the conventional tax which is to be reduced using emission tax revenue were to be examined in more detail. And above all, estimates, or at least lower bounds, of the values of reduced emissions will have to be found, unless there is already a binding commitment to reduce emissions.

In addition, distributional issues (can poor people afford coal for heating, etc.), or who gains or loses from revenue neutral tax reform are be a crucial issue and is one that has been largely neglected to date. Indeed, the proponents of wider-ranging "ecological tax reform" must not lose sight of political realities. It may be better economically to return emission tax revenue as a lower distortionary tax than as lump sums, leaving aside distributional concerns, for lump-sum transfer may be preferable from this point of view, but the political reality of the situation must not be forgotten. It is vital that the academic debate does not distract attention away from the practical policy applications. After all, it would seem that the double dividend debate has, to some extent, chosen to ignore the standard efficiency, in terms of abatement cost, arguments for environmental taxation. The existence of only the weak form of the second dividend is preferable to (increased) regulatory standards and may be the only way to deal with the problem of carbon caused global warming. However, it is clear that distributional issues are of prime importance from the point of view of political acceptability and it is this issue that this thesis concentrates on.

Notes:

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[1]An early version of this chapter became the basis for the author's contribution to two papers in collaboration with Jack Pezzey of the University of York (Park and Pezzey (1999) and Pezzey and Park (1999)). The nature of this collaborative process led to the introduction of a new structure to the chapter.

[2]Note the distinction between a policy and a policy move, the latter being a switch between policies. This is important as any existing regulation or environmental policy will have an impact on a newly introduced policy.

[3]Revenue may however be retained and used to fund further public expenditure or reduce government debt. Bovenberg and van der Pleog (1996) include the optimum level of public spending in their analysis of revenue-neutral tax reform.

[4]A lump-sum redistribution, although neutral in tax efficiency terms may be desirable if equity issues are important. See Section 1.2.2.

[5]It may be thought that BC represents the environmental dividend but, as will be seen, this is not the case.

[6]There is some evidence that this second environmental effect is so small as to be insignificant. See Bovenberg and Goulder (1995).

[7]Lump-sum redistribution is almost certainly impractical in reality.

[8]The theoretical model is an extension of Bovenberg and de Mooij (1994b) and the empirical general equilibrium is that used in Goulder (1995a).

[9] See Section 1.5 for further discussion of the choice of revenue recycling instrument.

[10] It should be noted that this result is conditional on the authors use of 1974 production technology.

[11]One should also mention the introduction of smokeless zones in cities, which achieved a major reduction in SO2 emissions by simply banning small-scale coal burning. Whether one calls this an input standard or a technology standard hardly matters, since the fuel type and the furnace type are jointly determined.

[12]Most logically, standards would be set in terms of the total emissions from a site, often known as the "bubble" policy in the USA, rather than in terms of emissions from one stack, or emissions concentrations.

[13]Any problems of unfairness caused by taxing carbon which ends up locked up in products, e.g. in plastics, are ignored here.

[14]The prime ethical assumption is that the objective of policy is to maximise the present value of welfare using a constant exponential discount rate applied over the lifetimes of several generations.

[15]Although the point made previously with regard to the interaction between standards for any pollutant and energy use should not be forgotten.

[16]This model is not included as it uses lump-sum transfers.

[17]Equivalent to employers National Insurance contributions in the UK.

[18]The inclusion of revenue being returned through energy efficiency subsides maybe considered as being outside the bounds of what could be termed the 'standard' double dividend hypothesis.

[19]The key is that the tax schedule must be linear. It is possible to include a notion of tax allowances and then a single income tax rate as this still gives a linear function but it is not possible to have a realistic income tax structure with tax bands. Such a system is non-linear and may result in multiple equilibria.

[20]Employers National Insurance contributions in the UK.

[21]If there was a switch in the burden of taxation from capital to labour and the marginal productivity of capital was higher than the marginal productivity of labour.

[22]It is quite clear that this is a simplification.

Chapter 2 - A simple general equilibrium model

This chapter follows Bovenberg and de Mooij (1994b) closely but expands their model, which is based on identical households, to allow for differentiated households. At the same time, the expanded model presented here allows a direct exposition of their basic result.

The chapter is laid out as follows. Section 2.1 details the basic form and assumptions of the model. Section 2.2 calculates an expression for the welfare effects in the model and section 2.3 extends this analysis, by solving the model for employment effects. Section 2.4 makes the assumption of a single representative household and outlines, in depth, the conclusions of Bovenberg and de Mooij (1994b). Section 2.5 uses the ability of this form of the model to deal with differentiated households to analyse distributional issues and, finally, section 2.6 concludes.

2.1 The model

The model is a relatively simplistic general equilibrium model but is close to the most complicated model that can be solved without parameterisation. Indeed, if a more complicated theoretical model were technically feasible, it is likely that interpretation of the results would not be.

The model consists of a household sector with n households, who need not be identical, a government sector, responsible for public spending and taxation and two production sectors producing clean, C, and dirty, D, consumption goods respectively.

A simple linear technology describes production:

$$(2.1) \qquad h\sum_{i=1}^{n} L_i \equiv hL = \sum_{i=1}^{n} C_i + \sum_{i=1}^{n} D_i + G \equiv C + D + G$$

where X_i represents household levels of a variable and X represents economy levels of a variable. Labour, L, is the only input into production and total labour supply is the sum of the labour supply of individual households, L_i (i=1,...,n). Labour productivity, h, is constant and output is divided between public consumption (government spending), G, as well as the consumption of the clean and dirty private consumption goods, denoted by C and D respectively, as above. The total consumption of private consumption goods is made up of the sum of individual household consumption. Units are normalised so that the constant rates of transformation between the three produced quantities are unity. In addition all private commodities are expressed in per capita terms.

The basic form of an individual household's utility function is:

(2.2) $U_i = u_i(C_i, D_i, V_i, G, E)$

The two public goods, public consumption, G, and environmental quality, E, enter individual household utility. The household takes the supply of these two good as given. In optimising its utility the household adopts the demands for private goods (clean and dirty consumption and leisure, V) as instruments.

The inclusion of the quality of the natural environment in the household utility function allows the interaction between environmental and labour market distortions to be examined in a second best framework. The environmental distortion comes about because households do not take into account the adverse effect of their dirty consumption on environmental quality. More specifically the functional form of the utility function is such that both public goods, public spending and environmental quality are (weakly) separable from private goods, leisure, clean and dirty consumption. Thus environmental quality and public spending have no impact on private consumption or leisure and vice versa.

The effect of aggregate consumption of the dirty good on environmental quality is given by:

(2.3) $E = e\left(\sum_{i=1}^{n} D_i\right) = e(D), \textit{ where } \frac{de}{dD} < 0$

The model, by including a leisure-work trade-off, endogenises labour supply and thus the labour-market distortion originates in a tax, t_L, on labour income. The level of household leisure, V, is given by the household potential labour supply[1], L_i^S, minus actual labour supplied, L_i. In addition the government imposes a pollution tax, t_D, on dirty consumption.

Thus, the household budget constraint is given by:

(2.4) $C_i + (1+t_D)D_i = h(1-t_L)(L_i^S - V_i)$

Household consumption of private goods is equal to net labour income. Combining the budget constraint of all households (2.4) and market equilibrium gives, by Walras' law, the government budget constraint[2]:

(2.5) $G = t_D \sum_i D_i + t_L \sum_i L_i$

Public spending is thus equal to the total tax revenue gained from the taxes on labour and the dirty good.

2.2 Welfare effects

The first order conditions characterising optimum household behaviour arise from the Lagrangean:

(2.6) $\underset{\max V_i, C_i, D_i}{\ell_i} = u(C_i, D_i, V_i, G, E) + \lambda_i \left(h(1-t_L)(L_i^S - V_i) - C_i - (1+t_D)D_i\right)$

and are given by:

(2.7a) $\frac{\partial u_i}{\partial V_i} = \lambda_i h(1-t_L)$

(2.7b) $\frac{\partial u_i}{\partial C_i} = \lambda_i$

(2.7c) $\frac{\partial u_i}{\partial D_i} = \lambda_i(1+t_D)$, where λ_i is the marginal utility of income.

The welfare effects, on an individual household, of a revenue neutral change in the tax mix (i.e. dG=0) are given[3] by:

$$(2.8) \quad dU_i = -\frac{\partial u_i}{\partial V_i}dL_i + \frac{\partial u_i}{\partial C_i}dC_i + \frac{\partial u_i}{\partial D_i}dD_i + \frac{\partial u_i}{\partial E}\left[\frac{de}{dD}\right]dD \text{ , where } D=\sum_i D_i$$

The first three terms on the RHS represent the effect on the household from changes in its own behaviour (labour supply, dirty and clean consumption) and the final term represents the environmental effect on the household from total changes (across all households) in the consumption of the dirty good.

Substituting the first order conditions for utility maximisation from (2.7) into (2.8) gives:

$$(2.9) \quad dU_i = -\lambda_i h(1-t_L)dL_i + \lambda_i dC_i + \lambda_i(1+t_D)dD_i + \frac{\partial u_i}{\partial E}\left[\frac{de}{dD}\right]dD$$

Dividing by λ_i and summing across all households gives:

$$(2.10) \quad \sum_i \frac{dU_i}{\lambda_i} = -h(1-t_L)dL + dC + (1+t_D)dD + \sum_i\left(\frac{1}{\lambda_i}\frac{\partial u_i}{\partial E}\left[\frac{de}{dD}\right]dD\right)$$

Taking the total differential of (2.1), and again setting dG=0 gives

$$(2.11) \quad hdL = dC + dD + dG$$

Substituting (2.11) into (2.10) to eliminate dC and rearranging gives:

$$(2.12) \quad \sum_i \frac{dU_i}{\lambda_i} = ht_L dL + \left[t_D - \sum_i\left(-\frac{1}{\lambda_i}\frac{\partial u_i}{\partial E}\left[\frac{de}{dD}\right]\right)\right]dD$$

The first term on the RHS of (2.12) is the effect on the labour market distortion, due to the effect of the tax on labour income. The second term represents the effect on the environmental distortion. The welfare effect of a marginal increase in consumption of the dirty good, i.e. the term in dD in square brackets, is broken down into the social benefit of additional tax revenue due to a wider tax base (the first term in the bracket) and a term representing the marginal social damage from increased pollution (the second term in the bracket).

When there is no need to finance public spending through distortionary taxation on labour (t_L=0), the 'first-best' case the optimal value of the tax on the dirty good, t_D, would simply be the Pigouvian tax which fully internalises the externality effects of the environmentally damaging good:

$$(2.13) \qquad t_D = \left[-\frac{de}{dD}\right]\sum_i\left(\frac{1}{\lambda_i}\frac{\partial u_i}{\partial E}\right)$$

With a Pigouvian tax[4], in the absence of distortionary labour market taxation, the beneficial environmental effects of lower consumption of the dirty good exactly offset the welfare loss due to a decline in the tax base (from the reduction in consumption of the dirty good). Changes in employment do not affect welfare as in a distortion free labour market the social opportunity costs of additional employment (in terms of leisure) exactly offset the social benefits (in terms of increased consumption).

The distributional implications of (2.12) and (2.13) are detailed below in section 2.5.

In the presence of a distortionary tax on labour (t_L>0), (2.12) demonstrates that the welfare effect of revenue neutral changes in the tax mix would depend on changes in employment. The following section explores this issue.

2.3 Employment effects

In order to examine employment effects in the context of a revenue neutral tax change, the model is manipulated to show the variables in terms of relative changes[5]. This process means, in effect, the expositional form of the model is one of comparative statics, which makes interpretation more straightforward.

Taking the total differential[6] of the government budget constraint, from (2.5), and again setting the change in public spending to zero, gives:

$$(2.14)\quad dt_D \sum_i D_i + t_D \sum_i dD_i + dt_L h \sum_i L_i + t_L h \sum_i dL_i = 0$$

Dividing through by (1-t_L)h□L_i and rearranging, gives:

$$(2.15)\quad \frac{t_D \sum_i dD_i}{(1-t_L)h\sum_i L_i} + \frac{t_L \sum_i dL_i}{(1-t_L)\sum_i L_i} = -\frac{dt_D \sum_i D_i}{(1-t_L)h\sum_i L_i} - \frac{dt_L \sum_i L_i}{(1-t_L)\sum_i L_i}$$

Defining the relative change in the tax rate on labour, $\tilde{t}_L$ and the relative change in household employment, $\tilde{L}_i$, by $\tilde{t}_L = dt_L/(1-t_L)$ and $\tilde{L}_i = dL_i \big/ \sum_i L_i$ respectively and substituting into (2.15) gives:

$$(2.16)\quad \frac{t_D \sum_i dD_i}{(1-t_L)h\sum_i L_i} + \frac{t_L}{(1-t_L)} \sum_i \tilde{L}_i = -\frac{dt_D \sum_i D_i}{(1-t_L)h\sum_i L_i} - \tilde{t}_L$$

Further defining the share of dirty goods in overall household consumption, Φ_D, as $\Phi_D = (1+t_D)\big/\left[C+(1+t_D)D\right]$, the share of dirty goods in terms of overall output, a_D, as $a_D = \sum_i D_i / h\sum_i L_i = (1-t_L)\Phi_D/(1+t_D)$, the proportional tax change in the tax rate on the dirty good, $\tilde{t}_D$, as $\tilde{t}_D = dt_D/(1+t_D)$ and the relative change in household consumption of dirty goods, $\tilde{D}_i$, as $\tilde{D}_i = dD_i \big/ \sum_i D_i$, substituting and rearranging gives:

$$(2.17)\quad \frac{\left[t_L \sum_i \tilde{L}_i + t_D a_D \sum_i \tilde{D}_i\right]}{(1-t_L)} = -\tilde{t}_L - \Phi_D \tilde{t}_D$$

The LHS of (2.17), is the 'tax-base' effect, $\tilde{b}^t$. The first term is the effect on the base of the labour tax and the second term is the effect on the base of the pollution tax. Given a fixed before tax wage[7], h, real after tax wages, w, are defined as w=h(1-t_L)/p where p is the consumption price index. The first term in the RHS of (2.17) is the change in the labour tax rate and the second term is the share of dirty good consumption in overall household consumption times by the change in the tax rate on the dirty good and can thus be interpreted as the change in the consumption price index. Examining the definition of w, the RHS of (2.17) is the change in the real after tax wage. Hence (2.17) reveals that the real after tax wage, w, falls if the tax base erodes.

In order to calculate household labour supply and demand for dirty goods the separability assumptions alluded to above regarding household utility are formalised . Public goods, G and E, are (weakly) separable from private goods, C, D and V. Clean and dirty goods are aggregated into a composite consumption good, Q. Formally:

$$(2.18)\quad U_i = u_i\left(G, E, H_i\left(V_i, Q_i\left(C_i, D_i\right)\right)\right)$$

Optimising the sub-utility function H_i in (2.18) subject to the household budget constraint gives[8]:

$$(2.19)\quad \tilde{L}_i = \theta_i^l \tilde{w}$$

The change in the labour supply of household i is given by the household's uncompensated wage elasticity of labour supply, $\theta^l{}_i$, times the change in the real after tax wage. Labour supply depends only on the real-after tax wage due to the separability assumptions outlined above. Summing across households we have:

$$(2.20)\quad \sum_i \tilde{L}_i = \sum_i \theta_i^l \tilde{w}$$

A similar process to that for labour supply above gives the following expression for the household demand for dirty consumption:

$$(2.21)\quad \tilde{D}_i = \tilde{L}_i + \tilde{w} + (1 - \Phi_D)\sigma_i \tilde{t}_D$$

where σ_i represents the household substitution elasticity between clean and dirty consumption in the sub-utility function, Q_i.

Substituting (2.20) and (2.21) into (2.17) gives the solution for employment:

$$(2.22)\quad \sum_i \mu \tilde{L}_i = -t_D a_D(1-\Phi_D)\tilde{t}_D \sum_i \sigma_i \theta_i^l \text{ where } \mu_i = 1-(t_L + a_D t_D)(1+\theta_i^l)$$

The term with L_i on the LHS, μ_i, is strictly greater than zero[9]. Before examining distributional issues, the following section examines the basic Bovenberg and de Mooij (1994) result.

2.4 The Bovenberg and de Mooij result

By assuming a single representative household, (i=1), (2.22) allows Bovenberg and de Mooij's result to be directly examined. (2.22) becomes:

$$(2.23)\quad \mu\tilde{L} = -\theta_D a_D(1-\Phi_D)\sigma\tilde{t}_D \text{ where } \mu = 1-(t_L + a_D t_D)(1+\theta$$

It should be noted that previously L_i was defined as the relative change in household employment compared with total employment. In the case of a single household however, total employment is equal to household employment and so (2.23) shows the relative change in household (and thus, in this case, total) employment. Thus, provided the pollution tax is at a positive initial level (t_D>0), then a marginal increase in the pollution tax will reduce employment provided the uncompensated wage elasticity of labour supply, θ^l, is positive. Most empirical studies indeed suggest that θ^l is positive (see e.g. Hausman, 1985). The transmission mechanism for this change is as follows.

The decline in employment is due to a fall in the real after tax wage, w, (from 2.19), eroding the incentives to supply labour. This fall in the real after tax wage takes place because the reduced rate of labour taxation, t_L, is unable to fully compensate labour for the adverse effects of the increased pollution tax on their real wage. The reason for this effect is the erosion of the base of the environmental tax - the higher environmental tax causes households to substitute clean for dirty consumption.

From (2.17) and including the single household assumption, the tax base effect is given by:

$$(2.24)\quad \tilde{b}' \equiv \frac{\left\lfloor t_L\tilde{L}_i + t_D a_D \tilde{D}_i \right\rfloor}{(1-t_L)} = -\tilde{t}_L - \Phi_D \tilde{t}_D \equiv \tilde{w}$$

The revenue neutral change imposed by the model means that, at the margin, $t_L\tilde{L}_i + t_D\tilde{D}_i = 0$. Remembering that t_L falls and t_D rises, comparing this expression with (2.24) shows that the tax base will fall as a_D, the output share of dirty goods, is less than one. This fall in the tax base results in the fall in the real wage, again from (2.24).

The key point is that in order to maintain overall tax revenues the government is unable to reduce the tax on labour sufficiently to offset the effect on the real-wage and hence employment of the higher pollution tax. The pollution tax, which amounts to a narrow base tax, is less efficient in raising revenue than the broad-based labour tax, as the pollution tax changes the composition of the consumption basket[10]. This change in the consumption basket, a switch from dirty to clean goods, enhances environmental quality but reduces the real after tax income from work. In a sense there is an increase in the overall supply of collective goods, in terms of the enhanced environmental quality and because the costs of collective goods, including a cleaner environment, are borne by labour, this reduces the incentive to supply labour.

Returning to (2.12) and again imposing the single household assumption, welfare effects of the tax changes can be examined:

$$(2.25)\quad \frac{dU}{\lambda} = ht_L dL + \left[t_D - \left(\frac{1}{\lambda}\frac{\partial u}{\partial E}\left[-\frac{de}{dD}\right]\right)\right]dD$$

Without a pre-existing distortionary labour tax, (t_L=0), a marginal reduction in the pollution tax below its Pigouvian level would not affect welfare[11]. On the other hand, if the initial tax on labour was positive, welfare would increase due to this marginal reduction in t_D. The second term on the RHS of (2.25) would still be zero but from (2.23) the reduction in t_D would increase employment giving a positive first term. Thus in this 'second-best' case, the optimal environmental tax lies below the social damage from pollution or the Pigouvian level.

The government could return the revenue from pollution taxes in terms of lump-sum transfers, or indeed by increasing public spending, rather than by cutting taxes on labour. In this case however, the associated higher levels of distortionary taxation and transfers imply that employment would decline more than in the case where labour taxes were reduced. This lower level of employment would reduce the labour tax base and thus worsen the pre-existing distortion. Thus, in the presence of distortionary taxation, revenue-neutral pollution taxes do allow, in the terminology of the previous chapter, a 'weak' double dividend in the sense that a cost reduction can be achieved compared with either returning revenues in a lump-sum fashion or retaining them.

When distributional effects are taken into consideration, the situation becomes more complicated and this is dealt with in the following section.

2.5 Distributional issues

To examine the distributional implications of the tax reform considered it is useful to respecify (2.12) and (2.22) in terms of a single household[12].

$$(2.26)\quad \frac{dU_i}{\lambda_i} = ht_L dL_i + \left[t_D + \left(\frac{1}{\lambda_i}\frac{\partial u_i}{\partial E}\left[\frac{de}{dD}\right]\right)\right]dD$$

$$(2.27)\quad \mu_i\tilde{L}_i = -t_D a_D(1-\Phi_D)\tilde{t}_D\sigma_i\theta_i^l \text{ where } \mu_i = 1-(t_L + a_D t_D)(1+\theta_i^l)$$

An examination of (2.27) shows that the change in the relative employment of household i, $\tilde{L}_i$, where to recap $\tilde{L}_i = dL_i / \sum_i L_i$, is dependant on the parameters θ_i^l and σ_i where θ_i^l and σ_i are the household uncompensated wage elasticity of labour supply and substitution elasticity between clean and dirty consumption respectively. It is useful to rephrase (2.27):

$$(2.28)\quad \frac{1-(t_L + a_D t_D)(1+\theta_i^l)}{-t_D a_D(1-\Phi_D)\tilde{t}_D\theta_i^l}\tilde{L}_i = \sigma_i$$

(2.28) shows the relationship, all else being held constant, between the household substitution elasticity between dirty and clean goods and the household uncompensated wage elasticity of labour supply, for a given change (rise) in t_D in relative household labour supply[13]. A plot[14] of (2.28) is shown in Figure 2.1.

Figure 2.1 - Relationship between θ_i^l and σ_i for a given change in household labour supply.

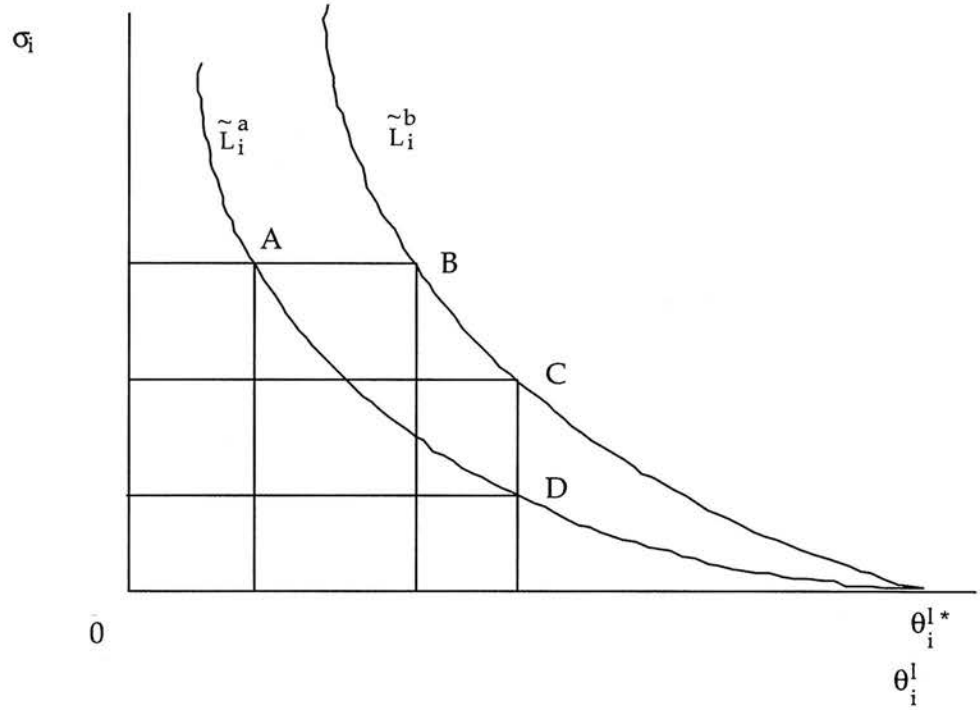


Figure 2.1 shows the inverse relationship between θ_i^l and σ_i for a given fall in household labour supply. θ^{l*} represents the point at which the Laffer curve ceases to be upward sloping (μ_i=0). The two curves in Figure 2.1, $\tilde{L}_i{}^a$ and $\tilde{L}_i{}^b$, vary the change in employment. $\tilde{L}_i{}^b$ represents a greater fall in employment than $\tilde{L}_i{}^a$, but both are for the same relative change in t_D.

If two households have an identical level of marginal substitution between dirty and clean goods, then, as one would expect, the household with the greater wage elasticity of labour supply will face the largest fall in employment (point A and point B on Figure 2.1). Alternatively, if two households have an identical of wage elasticity of labour supply then the household with the greater elasticity of substitution between dirty and clean goods will face the largest fall in employment (point C and D on Figure 2.1).

So how are wage elasticity of labour supply and elasticity of substitution between dirty and clean goods likely to vary with household income? Considering wage elasticity of labour, it is likely that higher income households will have higher levels as, in some sense, they are able to 'afford' to reduce their labour supply in response to a lower real wage. Low income households on the other hand, who may be close to subsistence levels, are likely to respond to a cut in real wages to a lesser degree[15]. Thus, it would appear that lower income households will have a lower wage elasticity of supply than higher income households and, as such, other things being equal will face a lower fall in employment.

Examining the elasticity of substitution between dirty and clean consumption goods, the exact nature of the dirty good is obviously important. If the dirty good is a necessity, e.g., energy, then the substitutability between it and the clean consumption good is likely to be relatively low for all households. However, it may be argued that, in the case of, say, energy, the lower the income of the household, the closer they are likely to be to subsistence levels of consumption of the dirty good, and thus, the lower the elasticity of substitution. Higher income households on the other hand may have scope to reduce wasteful consumption and thus have a higher elasticity of substitution.

So it would appear that, for both parameters, the likely situation is that their values will be lower for lower income households. As such, it is likely that lower income households will endure a lower relative change in employment. The effect of the tax reform may well be progressive in nature, in terms of employment.

Turning to welfare, the situation is more complicated. Examining (2.12), respecified for an individual household we have:

$$\text{(2.29)}\quad \frac{dU_i}{\lambda_i} = ht_L dL_i + \left[t_D - \left(\frac{1}{\lambda}\frac{\partial u_i}{\partial E}\left[-\frac{de}{dD}\right]\right)\right]dD$$

This expression is a good proxy for the relative change in welfare due to the inclusion of the marginal utility of income term on the LHS. The Pigouvian tax detailed in (2.13), if there is no pre-existing labour tax (t_L=0) will have a distributional impact in the model, if the households are differentiated. The impact on any particular household will depend on that household's marginal valuation of the environment, $\partial u_i / \partial E$. Households with a high environmental valuation will experience a welfare gain whilst those with low environmental valuations will experience a welfare loss. Without quantification of this valuation the effect is ambiguous.

If we differentiate households by income, as is natural, it may be argued that higher income households have the resources to be able to be concerned about the environment and thus may place a higher value on environmental quality. Alternatively, higher income households may be more able to isolate themselves from poor environmental quality by relocating away from the pollutant source, meaning as they are able to avoid environmental damage they may value the environment less highly than lower income households who are geographically immobile.. Which of these arguments, if either, holds true is open to debate, but will obviously depend on the nature of the environmental externality being considered. The first argument may be suited to pollution that has a global impact, e.g. CO_2, whilst the second would be more relevant to a pollutant with a geographically localised impact such as SO_2. The first of the two arguments may, in reality, have more merit.

The basic argument outlined in Section 2.4, for the optimal environmental tax, in the presence of distortionary labour taxation, to be below Pigouvian levels is unaffected by any distributional breakdown. However, it was shown above that the relative change in employment, given a increased pollution tax, is lower for lower income households. Given the uncertainty about relative environmental valuation it is difficult to draw any firm implications in terms of overall relative welfare changes. It may be argued that, given the postulated higher elasticity of substitution between dirty and clean goods of higher income households, lower income households may gain from the increased environmental quality caused by the reduction in dirty consumption which is undertaken primarily by higher income households. But it must be reiterated that the overall relative welfare change is dependant on the environmental valuation of households.

In considering the alternative revenue recycling instrument, alluded to above, of increased lump-sum transfers, the situation becomes more complicated. As mentioned above, the associated higher levels of distortionary taxation would mean that employment would decline more than in the case in which labour taxes are cut. The overall effect is less attractive than the use of the revenue to reduce labour taxes. However, given the lower employment effects that lower income households face, lower income households may see a relative gain due to the higher benefit they would receive from increased transfers.

This is an issue that will be addressed in the following chapters which present a more complicated empirical approach. It should be noted at this point that the difficulty in quantifying environmental changes[16] empirically presents a difficult in what follows. The approach used in the following chapter, is to use potential environmental valuation as a bench mark for comparison. This is facilitated by the relatively straightforward form of the model's results. In the case of the CGE model, specific to carbon taxation, that forms the remainder of this thesis, the form of the results generated is much more complex and the approach is to consider environmental effects only in the sense of achieving given levels of CO_2 emissions.

2.6 Conclusion

This chapter has extended the model of Bovenberg and de Mooij (1994b) to allow for differentiated households. The form of the expansion allowed their results, alluded to in chapter 1, to be presented in detail. The basic story is that a revenue neutral increase in a pollution tax in the presence of distortionary labour taxation will cause a fall in employment but will be preferable to the revenue being retained or being recycled by lump-sum transfer. The double dividend of revenue-neutral environmental taxation exists in, to use the terminology of Goulder (1995), its weak form.

This fall in employment is due to a fall in the real after tax wage, w, reducing incentives to supply labour. The fall in the real after tax wage takes place because the reduced rate of labour taxation is unable to fully compensate labour for the adverse effects of the increased pollution tax on their real wage. This takes place because of an erosion of the base of the environmental tax.

If the households in the model are differentiated by income, then sensible assumptions about the differences in the wage elasticity of labour supply and the substitutability of clean and dirty consumption goods between households result in lower income households facing a smaller relative change in employment. Thus, the employment effect of such revenue-neutral tax reform is progressive.

The situation in terms of welfare is unclear as relative changes in welfare depend on the households' environmental valuation. It is not clear in what way the environmental valuation of households will change as one moves up through the income distribution. What is clear is that it will be dependant on the nature of the pollutant concerned. As such, a theoretical model such as that presented in this chapter is of little direct use to policy makers.

The situation is one where empirical analysis, focused on a specific pollutant is required. The focus for the remainder of this thesis will be on carbon taxation for the reasons outlined in chapter 1. Briefly, the key point is that no abatement technologies exist for CO_2 - it is the use of carbon based fuel that is the pollutant. This is in contrast to SO_2 which is a side-product of other production processes and as such there exists appropriate technology to reduce emissions.

Notes:

[1]The inclusion of different levels of household potential labour supply allows differentiation between households.
[2]From this point on $\sum_i$ will be used to denote the sum across all households.
[3]Namely the total differential of household utility from (2.2) with the change in G set to zero.
[4]With N identical households (2.13) exactly matches Bovenberg and de Mooij result that the Pigouvian tax is equal to:

$$t_D = N\left(-\frac{1}{\lambda_i}\frac{\partial u}{\partial E}\left[\frac{de}{dD}\right]\right).$$

[5]Bovenberg and de Mooij refer to this process as log-linearisation. See also Bovenberg (1989).
[6]As tax changes are now being dealt with, the tax rates, t_L and t_D, are no longer treated as constants.
[7]The before tax wage is simply equal to labour productivity.
[8]The specific maximisation problem is:

$$\max_{V_i,Q_i} H_i(V_i;Q_i) \text{ s.t. } \mathrm{pQ} = \mathrm{h}(1-\mathrm{t_L})(L_i^s - V_i)$$

Given this maximisation problem the uncompensated wage elasticity of labour supply, θ^l_i, is given by:

$$\theta_i^l = \frac{\partial L_i}{\partial w}\frac{w}{L_i}$$

The change in the supply of labour, L_i, in response to a change in the real wage, w, is:

$$\Delta L_i = \frac{\partial L_i}{\partial w}\Delta w$$

Thus, combining the two equations above:

$$\Delta L_i = \theta_i \frac{L_i}{w}\Delta w \Rightarrow \frac{\Delta L_i}{L_i} = \theta_i \frac{\Delta w}{w} \Rightarrow \tilde{L}_i = \theta_i \tilde{w}$$

[9]If $\mu_i<0$ then the household Laffer curve is downward sloping and the model is unstable.
[10]The labour tax does not distort the consumption basket due to the assumptions made about the form of the household utility function.
[11]Under an existing Pigouvian tax with no labour taxation, both the first term on the RHS and the term in brackets on the RHS of (2.25) would be equal to zero. A marginal reduction in t_D would have no impact.
[12]The functional form of both (2.12) and (2.22) is such that such a disagregation is trivial.
[13]Again subject to the condition that the Laffer curve is upward sloping.
[14]A plot of (2.28) is the same basic shape regardless of the parameterisation, provided that the condition that $\mu > 0$ is met.

[15]The existence of a comprehensive benefit system may negate this argument if it provides an incentive for low income households to reduce employment when faced with a lower real wage.

[16]Both in terms of household's environmental valuation and indeed the extent of any environmental effect.

Chapter 3 - An Empirical Partial Equilibrium Approach

3.1 Introduction

This chapter considers the simplest possible empirical approach to an examination of the distributional consequences of the double-dividend hypothesis, that of partial equilibrium analysis. The model that follows concentrates solely on the consumption or household sector of the economy and abstracts from effects on production.

While this approach is not in any major sense realistic, it does allow the exploration of some of the issues raised by the consideration of distributional effects within the broader context of the double dividend hypothesis. Once the absence of production sector affects is accepted, the model that is set up has the power to analysis the behaviour of the consumption sector in a detailed way. In the following model, the scenario considered should be viewed as dealing with consumer taxation only, i.e.. changes in the indirect taxation, faced by consumers, on final goods. An alternative view could be a situation where the production sector is assumed to simply pass on any increase in costs.

The most important loss generated by the concentration on the household side of the economy is that employment effects are ignored. This is a significant omission as even within the context of consumption taxation only, there are likely to be significant employment effects. If nothing else, the result will be that changes in the demand for various goods will affect the output and hence the employment of the sector of the economy that produces them.

Another important issue to note is that concentration on the environmental externalities in an economy arising solely from consumption goods is likely to grossly understate the total effect. It is quite obvious that the production sector is responsible for the generation of a majority of externalities. This will obviously depend on the nature of the externality being considered.

Table 1.1 (repeated from the previous chapter) gives some indication of this split for carbon dioxide (CO_2) and Sulphur Dioxide (SO_2).

Table 1.1 - Percentage of emissions generated by sector of the economy

	Percentage of total emissions coming from:	
Pollutant	Housing, commerce, transport and agriculture	Power stations, refineries and other industry.
CO_2	44	56
SO_2	11	89

Source: UK Dept. of Trade and Industry(1996), Digest of UK Energy Statistics, pp 190-1

It should be noted that the split shown in the table does not exactly correspond to the division imposed in the model as the model does not consider the use of transport and agriculture in the production sector, but it is sufficient to illustrate the point required. CO_2 is a much more suitable pollutant to consider in the way proposed than SO_2.

Thus the focus of the empirical part of this chapter will be on energy use. Section 3.2 details the theoretical layout of the model and defines the terms used. Section 3.3 examines the empirical analysis undertaken and Section 3.4 presents these empirical results. Finally, Section 3.5 concludes.

3.2 Theoretical layout of the model

The model outlined in this section follows closely the model of Schöb (1995) but is expanded to allow for differentiated households, thus allowing the examination of distributional effects. The analysis is simplistic in that it only considers final good (consumption) taxation in a small open economy. Section 3.2.1 derives the marginal social cost of public funds measure that is the basis of the model, Section 3.2.2 applies this measure theoretically and Section 3.2.3 considers the distributional issues raised.

3.2.1. Derivation of the marginal social cost of public funds measure

The model deals with h households, who need not be identical. There are n goods, denoted by $x_1,...x_d,..., x_n$. Goods x_1 to x_n (not x_d) are clean goods whose consumption causes no externality. Good x_d is a 'dirty' good whose consumption creates a negative externality, E. The externality is equal simply to the aggregate consumption of the dirty good:

$$(3.1) \quad E = \sum_h x_d^h$$

where x^h_d is the consumption of the dirty good by household h. Each household has a twice, continuously differentiable utility function $u(x_1,..., x_d,...., x_n, E)$, with positive marginal utilities except for the marginal utility of the environmental externality, u_E, which is negative. Good x_1 is chosen as numeraire and is assumed to be untaxed. A small, open economy assumption is made - producer prices are equal to world market prices and as such remain constant when tax-rates and consumer prices change. For simplicity these producer prices are set at unity. Thus, the indirect utility function of household h is given by:

$$(3.2) \quad v_h(t_2,...,t_d,...,t_N, T_h, E)$$

where t_i is the tax rate on the clean good i (i=1,..N) and t_d denotes the tax rate on the dirty good d. T_h is the lump-sum transfer from the government to household h, if applicable. This allows the construction of a utilitarian social welfare function of the form:

$$(3.3) \quad W = \sum_h v_h = \sum_h v_h(t_2,...,t_d,...,t_N, T_h, E)$$

The welfare change of a tax-rate change, when revenue is retained by the government, can be found by:

$$(3.4) \quad dW_k = \left(-\sum_h u_1 x_k^h + \frac{\partial E}{\partial t_k} \sum_h u_E^h \right)$$

with k = 1,...,N,d and u_1 is the marginal utility of the numuaire and u_E is the marginal utility of environmental damage. On examining (3.4), the first term in the bracket is the direct utility loss of each of the respective households, according to Roy's identity, arising from the tax change. The second term denotes the change in utility arising from a change in the environment. The first part of this term can be written as $\partial E/\partial t_k = \sum_h \partial x_d / \partial t_k$. A change in the consumer price of any good will change the level of emissions due to either the own price effect, when the good taxed is the dirty good (k=d), or the cross-price effect when the price of other goods changes (k=1,...,N, and k□d).

Total tax revenue, R, is given by

(3.5) $$R = \sum_h \left(\sum_{n=1}^{n} t_n x_n^h + t_d x_d^h \right) - \sum_h T_h$$

The breakdown of R is quite simple - the first term denotes the tax revenue due to the taxation of the clean goods, the second term the taxation of the dirty goods and the final term the lump-sum transfer to the households. It is now assumed that there is separability between emissions and the consumption of all private goods i.e. a change in emissions does not affect consumption or algebraically, $\partial x_k / \partial E = 0, \forall k$ We can now find the change in tax revenues resulting from a change of tax rate k:

(3.6) $$\frac{dR_k}{dt_k} \equiv \frac{\partial R}{\partial t_k} = \sum_h \left(x_k + \sum_i t_i \frac{\partial x_i}{\partial t_k} \right)$$

with i=1,...,d,...,N. A revenue-neutral environmental tax reform which increases the environmental tax on the dirty good, d, and reduces the tax on clean good, c, such that the revenue raised remains constant is described algebraically by:

(3.7) $$dR_d = -dR_c > 0$$

Thus, positive revenues, due to an increase in t_d, are equal to the amount to be refunded by decreasing t_c. To evaluate the welfare costs of a tax reform, the costs can be broken down into the direct cost, assuming that environmental quality remains constant, and the indirect benefit from the improvement in the environment. The direct cost or the marginal cost of public funds (MCF)[1] is determined by aggregating the utility loss of a single household over all households. The direct loss to a single household, ignoring environmental effects (denoted by $\bar{E}$), from a marginal increase in

t_k is given by: $du^*/dt_k|_{\bar{E}} = -x_k$, where $du^*=du/u_1$. Aggregating over all households and relating to the marginal tax revenues we have:

$$(3.8) \quad MCF_k = -\frac{\sum_h x_k^h}{\frac{\partial R}{\partial t_k}}$$

The MCF_k measures the social cost of one marginal unit of tax revenue raised by an increase in the tax rate on good k. It is important to note that a positive MCF associated with a tax rise is welfare diminishing and a positive MCF associated with a tax fall is welfare increasing. In other words the MCF measures the cost associated with a tax rise and the benefit associated with a tax fall. It is also important to stress that the MCF has no unit and thus is only useful for comparison between potential tax rate changes. The MCF measure, as stated above, does not measure any environmental effects associated with a change in tax rate, k.

The key point is that if the cross-price effect between any good, in this case good k, and the dirty good, d, is non-zero then the tax change will induce a change in demand for good d and the quality of the environment will change. This will have a resultant effect on welfare. To measure this effect the indirect loss or benefit from the environmental impact must be related to the revenues raised in a similar way to that above. This indirect welfare effect for a particular household is equal to the marginal utility of a change in emissions (u_E) times the change of emissions due to a change in t_k ($\partial E/\partial t_k$). Thus, summing up for all households, we have the marginal environmental impact (MEI) of the tax change:

$$(3.9) \quad MEI_k = \frac{\sum_h \left(u_E^h \cdot \frac{\partial E}{\partial t_k} \right)}{\frac{\partial R}{\partial t_k}} = \frac{\frac{\partial E}{\partial t_k} . \sum_h u_E^h}{\frac{\partial R}{\partial t_k}}$$

Making use of Equation (3.1), and the separability assumption between emissions and consumption we can define:

$$(3.10) \quad \frac{\partial E}{\partial t_k} = \sum_h \frac{\partial x_d^h}{\partial t_k}$$

and substituting into Equation (3.9), we have an alternative expression for MEI.

$$(3.11)\quad MEI_k = \frac{\sum_h \frac{\partial x_d^h}{\partial t_k} . \sum_h u_E^h}{\frac{\partial R}{\partial t_k}}$$

The first term in the numerator represents the Marginal Environmental Damage (MED) of a change in emissions. Thus, a negative MED, a reduction in emissions represents an environmental improvement. The second term represents the Marginal Environmental Valuation (MEV) of a rise in emissions. The MEV of a particular household is difficult to quantify but will be negative if households gain utility from environmental quality. It should be remembered that U_E and hence MEV is negative in sign. This is simply a result of the fact that a households' utility will decrease if it values the environment and the environment degrades. It is important to note that, given the above, a positive MEI associated with a tax rise denotes a benefit (negative MED from a fall in emissions and thus an improvement in the environment times a negative MEV) and a positive MEI associated with a tax cut denotes a loss - this is purely from the way the measure is defined. The marginal social cost of public funds (MSCF) is derived by subtracting the environmental benefit from the direct cost of the tax change.

$$(3.12)\quad MSCF_k = MCF_k - MEI_k$$

It is now crucial to note that a positive MSCF associated with a tax rise represents a decline in welfare, whilst a positive MSCF associated with a tax fall represents a rise in welfare. Decomposing the welfare effects of a tax change in this way allows the welfare effects of tax reform to be analysed in terms of both the efficiency of the tax system and the environmental damage. This is consistent with Schöb (1995). However the disaggregation by households allows examination of distributional effects. It should also be noted that, in this raw form, the measure takes no account of what happens to the revenue raised.

3.2.2 Theoretical application of the model

This section again follows Schöb (1995) very closely in its initial stages, but then goes on to examine the distributional factors that the extension to his model allows. The welfare effect of a revenue neutral tax change as described by equation (3.7) is a combination of the welfare effects of the two tax changes - the reduction in tax on the clean good and the increase in tax on the dirty good. The MSCF measure measures the cost, in terms of welfare, to society of a tax change. It is vital to note however that because of the raising of the tax on good d and the lowering of the tax on good c the welfare effect is measured by:

$$(3.13)\quad \frac{d\tilde{W}}{dR_d}\begin{Bmatrix} > \\ = \\ < \end{Bmatrix}0 \Leftrightarrow MSCF_c - MSCF_d\begin{Bmatrix} > \\ = \\ < \end{Bmatrix}0$$

This can be thought of intuitively as follows - the effect of lowering the tax rate on good c is to increase welfare by the $MSCF_c$, whilst the effect of raising the tax rate on good d is to reduce welfare by $MSCF_d$. Equation (3.1.14) decomposes the MSCF into the environmental dividend and the efficiency dividend using Equation (2.1.12).

$$(3.14)\quad \frac{d\tilde{W}}{dR_d}\begin{Bmatrix} > \\ = \\ < \end{Bmatrix}0 \Leftrightarrow (MEI_d - MEI_c) + (MCF_c - MCF_d)\begin{Bmatrix} > \\ = \\ < \end{Bmatrix}0$$

where $\tilde{W}$ represents the welfare associated with a revenue neutral tax change. In addition to examining the effect of imposing the environmental tax and reducing other tax rates, it is desirable to examine the consequences of using the revenue to reduce all tax rates - in effect a uniform VAT reduction. The MCF and MEI for this are shown in equations (2.1.15a) and (2.1.15b).

$$(3.15a)\quad MCF_{VAT} = \sum_i R_i \Big/ \sum_i \frac{R_i}{MCF_i}$$

$$(3.15b)\qquad MEI_{VAT} = \sum_i \frac{\partial E}{\partial t_i} \Big/ \sum_i \left(\sum_j x_j + \sum_k t_k \frac{\partial x_j}{\partial t_k} \right)$$

At this point it would be useful to summarise which sign of which measure for which good indicates a welfare improvement. This is shown in the Table 3.1.

Table 2.1 - Welfare implications of the sign of the MEI ad MCF measures.

	Good c	Good d
MEI +ve		Improvement
MEI -ve	Improvement	
MCF +ve	Improvement	
MCF -ve		Improvement

Equation (3.14) illustrates the environmental dividend (MEI_d - MEI_c), the strong form of the second dividend (MCF_c - MCF_d) and the weak form of the second dividend (MCF_c).

The environmental dividend is given by MEI_d, which will be positive if the environment improves due to the increased tax on good d, minus MEI_c, which will be positive if the environment is worsened by the reduced tax on good c. It is obvious that MEI_d will be positive[2], but the sign of MEI_c depends on the complementarity / substitutability relationship between the two goods. If good d is a complement to good c, then a reduction in the price of good c will increase demand for good d, *ceterus paribus* and MEI_c will be positive and either (i) the environmental dividend will be reduced (MEI_d > MEI_c) or it will be negative (MEI_c>MEI_d). If the goods are substitutes the environmental dividend will be reinforced by the fall in the price of good c reducing the demand for good d further and if there is no relationship between the two goods then the environmental dividend will be given solely by MEI_d, as MEI_c will be equal to zero.

The second dividend will take its strong form if MCF_c, the efficiency gain from the effect of the tax decrease on the rest of the tax system is positive and greater in magnitude than MCF_d, the efficiency loss from the tax increase on the dirty good. This will depend on the nature of the two goods and must be determined empirically. If MCF_c is positive, but lower in magnitude than MCF_d, then we have the weak form of the second dividend - the efficiency of the rest of the tax system is improved, but the efficiency of the tax system as a whole is reduced. In this case there will exist a critical value of the net MED (MED_d - MED_c) for which environmental dividend exactly outweighs the direct cost of the tax reform (MCF_c-MCF_d). This critical value, for a particular tax change, will be determined by the environmental valuation of the household or MEV. This value for environmental valuation will be termed Critical Marginal Environmental Valuation (CMEV).

3.2.3 Distributional issues

The distributional effect of a tax change can easily be ascertained from the model. The form of the social welfare function used means that all households have equal weight. Disaggregating Equation (3.14) to household level gives us:

$$(3.16)\quad \frac{d\tilde{W}_h}{dt_d} = \left(MEI_d^h - MEI_c^h\right) - \left(MCF_c^h - MCF_d^h\right)$$

Both MCF and MEI can be disaggregated in turn:

$$(3.17)\quad MCF_k^h = \frac{-\frac{du_h}{dt_k}\Big|_{\overline{E}}}{\frac{\partial R}{\partial t_k}}, MEI_k^h = \frac{\frac{\partial E}{\partial t_k}.u_E^h}{\frac{\partial R}{\partial t_k}},$$

and similarly for the VAT reduction measures in equations (3.15a) and (3.15b). This allows analysis of the issues of Pareto improvements and equity effects.

Assuming that the change to the tax system is welfare improving overall, it will be Pareto improving if:

$$(3.18)\quad \frac{d\tilde{W}_h}{dt_d} \geq 0, \forall\, h$$

If we assume there are H households, h = 1,...,H and they are ranked in income order in that household H has the highest income and household 1 the lowest then the basic possibilities of changes to equity are as follows:

$$(3.19)\quad \left.\begin{matrix} Increase \\ Decrease \\ Constant \end{matrix}\right\} \frac{d\tilde{W}_i / dt_d}{W_i} \left\{\begin{matrix} > \\ < \\ = \end{matrix}\right\} \frac{d\tilde{W}_j / dt_d}{W_j} \quad \forall i < j$$

The expressions in equation (2.1.19) represent the proportionate increase in welfare of the households i.e. the increase in welfare divided by its level. Thus, if a lower income household's welfare is increased proportionally more than a higher income households, then there will be an improvement in equity.

Equation (3.16) decomposes the MCF and MEI measures for individual households. A stated previously, the MEI measure is equal to the marginal environmental change associated with the relevant tax change times the household's valuation of the environment. Thus a household that values the environment highly will have a high MEI for a given tax-rate. On considering the relative importance of the environment between a high and a low income household the case can be argued in either direction.

Firstly, a high income household may value the environment more highly as it can afford to do so. This can be thought of as an 'altruistic' motive for environmental concern in that households may value the existence of a 'clean' environment even if it does not affect them directly. Alternatively, a low income household may be unable to isolate itself from environmental damage. In this case, what can be termed an 'impact' or 'effect' motive for environmental valuation, lower income households are likely to have greater concern. In reality, a mixture of both 'altruistic' and 'effect' motives will combine to give an overall view of the environment for a particular household. This will depend on both the precise nature of the externality being considered, in particular the location of its effects, and the income level of the individual. A traditional externality such as smoke from a factory will impact less on a higher income household, as they will be more easily able to locate away from the source. Thus impact motives are likely to be important for such a source for lower income households. However, an externality such as SO_2 emissions causing acid rain in Scandinavia and impacting, say, on biodiversity, may be of concern to higher income households for altruistic reasons.

The individual household MCF measure simply depends on the direct loss of utility from the tax change. If the dirty good is an inferior good, then lower income households will be hit harder, as will be the case if the clean good is a normal good and vice versa.

3.3 Empirical analysis

The model outlined in Section 3.2 was analysed empirically using Pashardes' (1993) Almost Ideal Demand System for the UK economy. Pashardes estimates an Almost Ideal Demand System for the UK economy using Family Expenditure Survey Data, 1970-86, for seven non-durable good types - Food, Alcohol, Fuel, Clothing, Transport, Other and Services. The problems of applying standard demand analysis to durable goods are detailed in Deaton and Muellbaur (1980).

3.3.1 The Almost Ideal Demand System of Pashardes (1993)

Under the Almost Ideal Demand System the budget share of good i, w_i is given by:

$$w_i = \alpha_i + \sum_j \gamma_{ij} \log p_j + \beta \log\left(\frac{Y}{P}\right) \tag{3.20}$$

where α_i, γ_{ij} and β are parameters, Y is expenditure, p_j is the price of good j and where P is a price Index defined by:

$$\log P = \alpha_0 + \sum a_k \log p_k + \frac{1}{2}\sum_k \sum_l \gamma_{kl} \log p_k \log p_l \tag{3.21}$$

The parameters α_i and α_0 vary between households and the γ_{ij} and β_i's define the interrelationships between goods and the income effects respectively. It should be noted that Equation (3.21) represents the exact form of the price index which Pashardes (1993) shows is preferable to the often used Stone approximation, which being linear simplifies estimation, but causes bias due to an omitted variable problem. The Stone Approximation Index is given by:

$$\log P = \sum_i w_i \log p_i \qquad (3.22)$$

Pashardes estimates the demand system in four ways: Macro data using the Stone Index (MaS), Macro data using the True Index (MaT), Micro data using the Stone Index (MiS) and Micro data using the True Index (MiT).

All four demand systems were used in order to achieve some analysis of the sensitivity of the results to variations in the parameters. Pashardes' results can be found in Appendix 3a.

3.3.2 Calibration of the model.

The Almost Ideal Demand System allows the parameters α_i and α_0 to vary between households. The model was calibrated using 1996 data on household budget shares and expenditure (normalised in terms of household 1) as shown in Table 3.2.

Table 3.2 - Data on household budget shares and expenditure (normalised in terms of household 1)

Household	Food	Alcohol	Fuel	Clothing	Transport	Other	Services	Normalised Expenditure
Average	0.256	0.087	0.076	0.075	0.178	0.127	0.202	3.3426
1	0.329	0.110	0.142	0.057	0.106	0.098	0.159	1
2	0.318	0.089	0.124	0.068	0.102	0.104	0.194	1.254
3	0.295	0.093	0.097	0.064	0.151	0.108	0.191	1.836
4	0.259	0.084	0.074	0.072	0.147	0.184	0.181	2.345
5	0.246	0.090	0.069	0.073	0.194	0.123	0.206	2.951
6	0.241	0.095	0.060	0.080	0.196	0.129	0.198	3.328
7	0.229	0.082	0.053	0.080	0.226	0.133	0.197	3.568
8	0.230	0.086	0.052	0.084	0.214	0.123	0.210	4.320
9	0.219	0.076	0.046	0.086	0.229	0.133	0.212	5.376
10	0.190	0.069	0.040	0.085	0.215	0.133	0.267	7.448

Producer prices were normalised to unity and consumer prices were calculated by adding the proportion of indirect tax on each good type shown in Table 3.3.

Table 3.3 - Proportion of indirect tax on the good types.

Food	Alcohol	Fuel	Clothing	Transport	Other	Services
0%	71.82%	17.5%	17.5%	17.5%	17.5%	17.5%

Source - Schöb 1995.

Four sets of data were available from the Macro and Micro data estimated by both the Stone Index and the True Index. For each set of data both the Exact and True index were used for calibration of household demand parameters. This gave rise to 8 sets of demand parameters as follows:

- Macro data using the Stone Index for estimation and the Stone Index for prediction - MaSS
- Macro data using the Stone Index for estimation and the True Index for prediction - MaST
- Macro data using the True Index for estimation and the Stone Index for prediction- MaTS
- Macro data using the True Index for estimation and the True Index for prediction- MaTT
- Micro data using the Stone Index for estimation and the Stone Index for prediction - MiSS
- Micro data using the Stone Index for estimation and the True Index for prediction - MiST
- Micro data using the True Index for estimation and the Stone Index for prediction - MiTS
- Micro data using the True Index for estimation and the True Index for prediction - MiTT

Although it may be theoretically dubious to use data estimated with one type of price index method for prediction with another type, the process allowed a more significant analysis of the sensitivity of the results to the demand parameters. The calibrated demand parameters are given in Appendix 3b.

3.3.3 Examination of the calibrated demand parameters

On examination of the calibrated demand parameters, a few stylised facts become apparent. The intercept terms for the MaST and MaTT models are significantly different from the parameters from the other models. It should be remembered, of course, that the models that use the true index for estimation (MaST, MaTT, MiST, MiTT) have an extra parameter, the price index co-efficient, than the models that use the Stone Index for approximation. However, all of the Micro data models share very similar intercept terms. Examination of the Price Index co-efficients for the Macro models shows that they vary considerably in sign and magnitude across households and are correlated strongly to each other. The Micro models have small, relatively constant values across all households. This would appear to be consistent with Pashardes' result that bias from the Stone Index is exacerbated in Macro data and throws suspicion[3] on the Macro models, especially the two that use the two different indices (MaST and MaTS).

The parameters for Food, Clothing, Other and Services are very similar across all models as opposed to those for Fuel in particular. This is perhaps a worry as it is Fuel, as the dirty good that we are primarily concerned with. As far as analysis across households is concerned, higher income households have generally higher intercepts for Food and Other, whilst for the other goods they remain relatively constant or there is no discernible pattern. The co-efficient for household 4 for Other is somewhat difficult to explain.

The following section details the calculation of the MCF and MSCF measures.

3.3.4 Calculation of the MCF and MSCF measures

The MCF and MEI for each good were calculated using equations (3.8) and (3.11). It should be noted that no value was initially implemented for the marginal environmental value, MEV, in equation (2.1.11). Rather the co-efficient or marginal environmental damage, MED was calculated. The use of this co-efficient is seen in the following sections. In addition to calculating the MCF, MEI and then the MSCF for an increase in indirect taxation (a VAT increase in effect) for each good, the MCF and MEI for an overall VAT change were also estimated using equations (3.15a) and (3.15b).

3.4 Results

Each of the models produces 11 by 8 = 160 ([[Households x MCF] + MED] x Goods {7+VAT}) initial values as its basic results which are then manipulated. These results are given in their entirety in Appendix 3c. The large amount of raw result data, particularly for the MCF, means that it is difficult to intuitively grasp what is happening. Thus, Section 3.4.1 deals solely with the MCF for the average household in order to generate a 'feel' for what is taking place. Section 3.4.2 then considers all households.

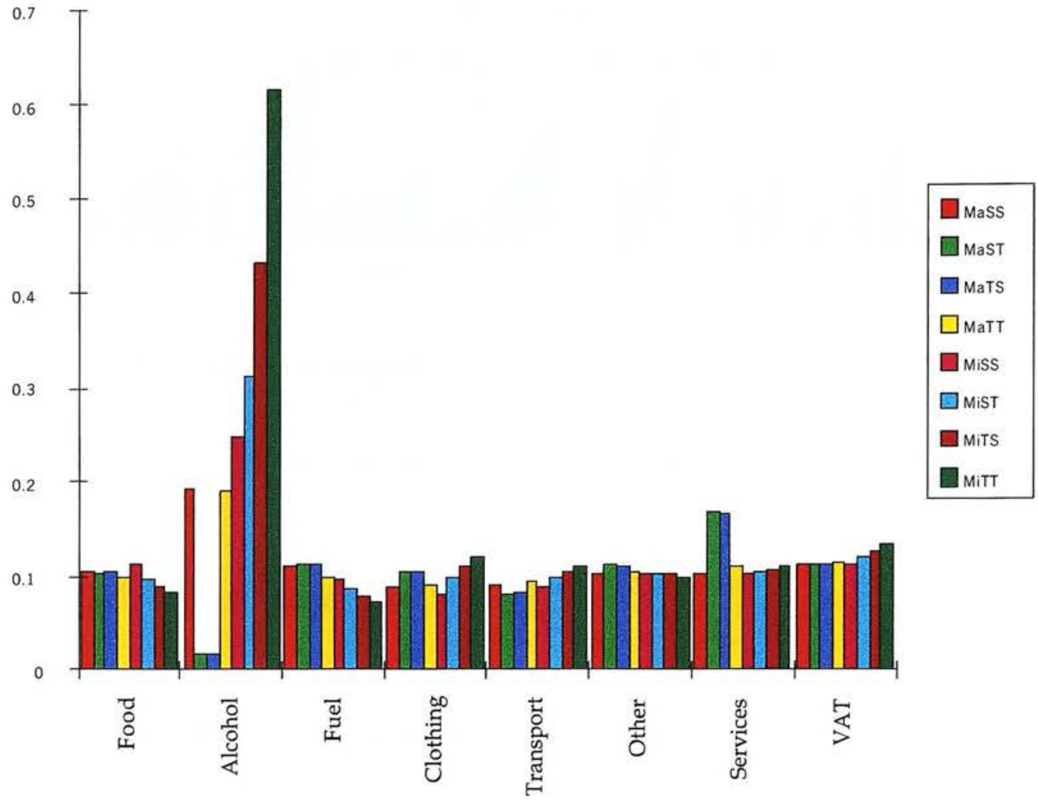
3.4.1 Results for the Average household

The results for the average household are shown in Table 3.4. and illustrated in Figure 3.1. Figure 3.1 clearly shows that the MCF is highest for Alcohol and also that there is the most variation between models for Alcohol. This is consistent with the initial high rate of tax on Alcohol as i) one would expect the MCF to be high in this case and ii) with a high initial tax rate small differences between models will be exacerbated. Examining the other goods, although the conclusions are not so obvious as the conclusions drawn for Alcohol, it can be seen that the MaST and MaTS models vary considerably from the others, particularly Services. This is consistent with Pashardes' result that bias from the Stone Index approximation is exacerbated with Macro data. Thus, using a mixture of indexes with the Macro data produces distorted results. These two models (MaST and MaTS) are excluded from any further analysis.

Table 3.4 - Results for the average household.

Model	Food	Alcohol	Fuel	Clothing	Transport	Other	Services	VAT
MaSS	0.104785	0.193875	0.11163	0.088246	0.092947	0.103702	0.102398	0.112865
MaST	0.101939	0.016596	0.112541	0.1056	0.081716	0.113004	0.16883	0.114009
MaTS	0.104187	0.01646	0.112339	0.105644	0.084742	0.109867	0.166242	0.113142
MaTT	0.100249	0.1894	0.098796	0.093279	0.093714	0.10549	0.110898	0.114854
MiSS	0.113362	0.249559	0.097306	0.081118	0.090574	0.102984	0.101587	0.11246
MiST	0.096406	0.313	0.086918	0.101011	0.099131	0.101539	0.104706	0.121344
MiTS	0.089083	0.434153	0.07997	0.110374	0.104062	0.101507	0.108535	0.127668
MiTT	0.083784	0.616397	0.073269	0.120881	0.111751	0.100662	0.11147	0.133789

Figure 3.1 - MCF for the average household.



After excluding the two 'mixed' Macro models (MaST and MaTS), it becomes apparent that the remaining results are broadly consistent with each other. The Macro models tend to understate values for Clothing and Transport and overstate values for Food and most significantly Fuel, compared with the Micro models. The next section will deal with all households.

3.4.2 Results for all Households

All results for the MCF can be found in Appendix 3c but are illustrated diagramatically in Figure 3.2 (a to f).

Figure 3.2a - MCF by household in the MaSS model

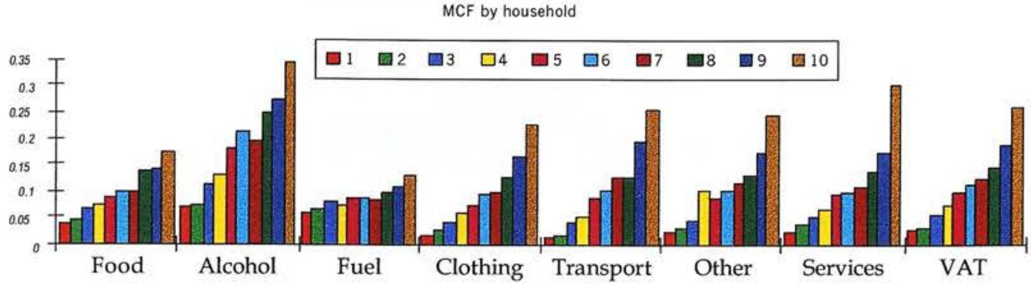


Figure 3.2b - MCF by household in the MaST model

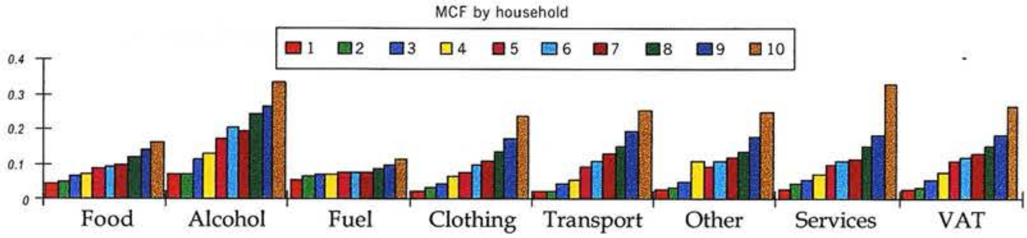


Figure 3.2c - MCF by household in the MiSS model

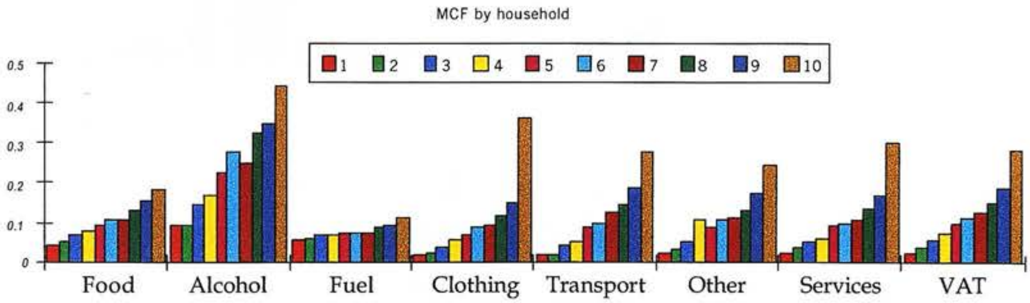


Figure 3.2d - MCF by household in the MiST model

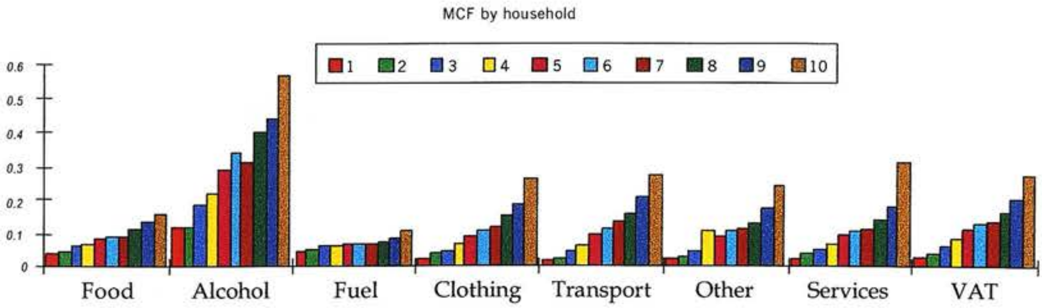


Figure 3.2e - MCF by household in the MiTS model.

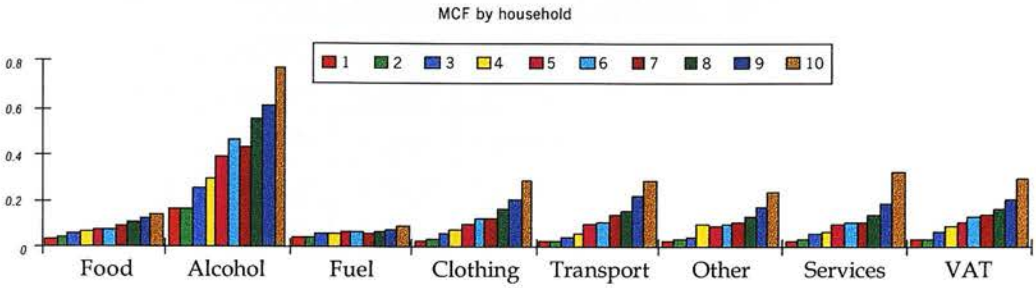
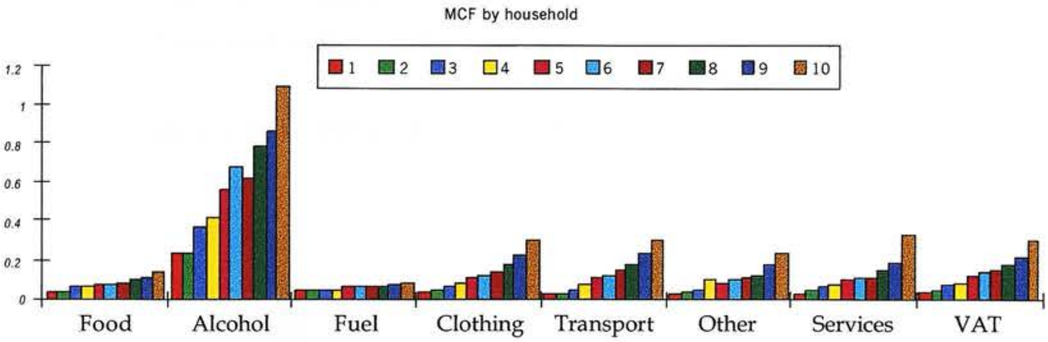


Figure 3.2f - MCF by household in the MiTT model



The results for all goods are broadly similar in that, as one would expect, the higher the income of the household, the higher the MCF the household faces from a rise in the tax rate on a particular good. One exception to this is Other which is bi-modal at household 4 and 10. Across models, the results for Food and Fuel seem to be overstated by Macro data and the results for Alcohol and to a lesser extent Transport are overstated by Micro data.

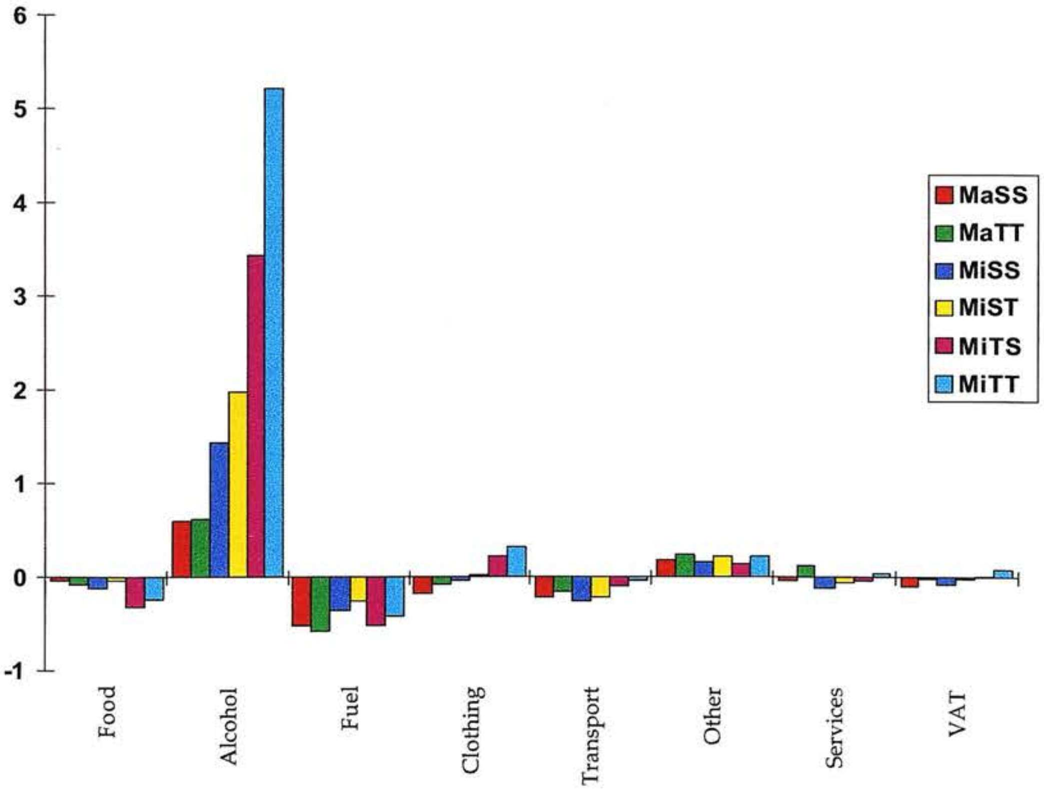
The marginal environmental damage (MED) co-efficients which are the same for all households are show in Table 3.5.

Table 3.5 - Marginal Environmental Damage co-efficients

Model	Food	Alcohol	Fuel	Clothing	Transport	Other	Services	VAT
MaSS	-0.03682	0.613905	-0.51676	-0.18077	-0.22098	0.17985	-0.02851	-0.0827
MaTT	-0.07893	0.629277	-0.57021	-0.07871	-0.16296	0.255552	0.117447	-0.01342
MiSS	-0.1116	1.451169	-0.35453	-0.03594	-0.25007	0.165688	-0.11787	-0.06814
MiST	-0.03215	1.981076	-0.2616	0.015364	-0.21367	0.229609	-0.05548	-0.00619
MiTS	-0.30749	3.450824	-0.51691	0.237012	-0.10376	0.152675	-0.03587	0.013884
MiTT	-0.23525	5.227079	-0.42104	0.330172	-0.04079	0.217513	0.03537	0.085004

The MED results show much greater variance than those for the MCF. A tax increase on Food, Fuel, Transport and Services is shown to be environmentally improving across all models and a tax increase on Clothing and VAT is environmentally improving across a majority of models. These results are illustrated in Figure 3.3.

Figure 3.3 - Marginal Environmental Damage coefficients



A somewhat surprising result is that a rise in Alcohol tax is severely environmentally damaging, a fact that is massively exaggerated by the micro models. This could conceivably be explained by the nature of the good in relation to Fuel (the dirty good). Although both goods are inferior in that lower income households spend proportionally more on them, alcohol could be considered a luxury and fuel a necessity. Thus, an increase in the price of Alcohol would induce a large amount of switching to Fuel. This is borne out by Pashardes (1993) who calculates the cross price elasticity of demand[4] (at average budget shares and reference prices) for alcohol and fuel to be 0.732. This is relatively large (compared with all other cross price elasticities except Alcohol and services) and is of a similar size to the own price elasticites of the commodities other than Alcohol. As a point of reference, these own price elasticities range from (minus) 0.550 for Food to (minus) 0.813 for Transport. The own price elasticity for Alcohol is (minus) 1.957.

Pashardes' elasticity results are reasonably consistent with those of Deaton and Muellbauer (1980) on Macro data and Browning and Meghir (1991) on micro data when the Stone or approximate index is used (by Pashardes). It should be noted that the purpose of Pashardes (1993) is to examine the bias generated by the use of this approximation compared with the more complex true index (See 3.21 and 3.22). Pashardes finds that there is indeed significant bias (with both data types) and a close examination shows that this bias is downward for the cross price elasticity of Fuel and Alcohol. Thus, although the large environmental damage resulting from a rise in the Alcohol tax is surprising it is consistent with both the AID system estimates that are used and, bearing in mind the comments above, other studies.

The MED results are interesting in that they show that the environment would benefit from a range of tax rises, not just one on fuel, although an increase in the tax on Fuel offers the greatest beneficial change. However, more importantly, when revenue-neutrality is considered, reducing tax rates on Food, Transport and Services and to some extent Clothing and VAT results in the overall environmental benefit being reduced. This is dealt with more thoroughly in the next section.

3.4.3. Revenue Neutrality

The revenue-neutral changes considered consist of raising the tax rate on Fuel and reducing the tax rate on each of the other goods in turn. This gives the results for MCF and MED reported in Appendix 3d. These results are illustrated for MCF for all households in Figure 3.4 (a to h).

Figure 3.4a - MCF for revenue neutral tax changes in MaSS model

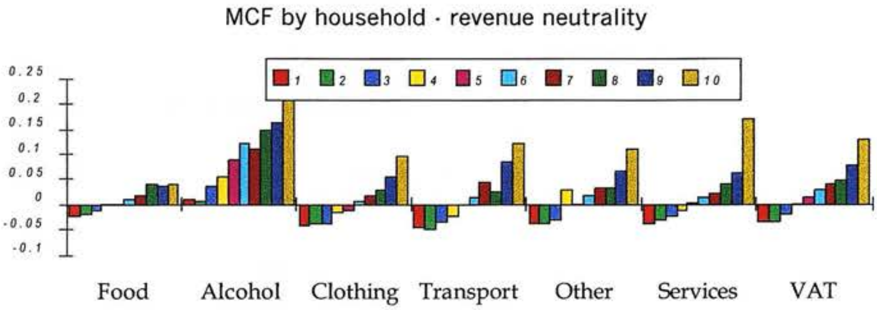


Figure 3.4b - MCF for revenue neutral tax changes in MaTT model

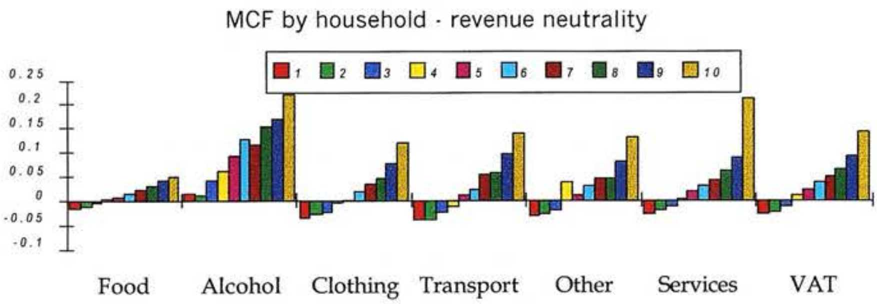


Figure 3.4c - MCF for revenue neutral tax changes in MiSS model

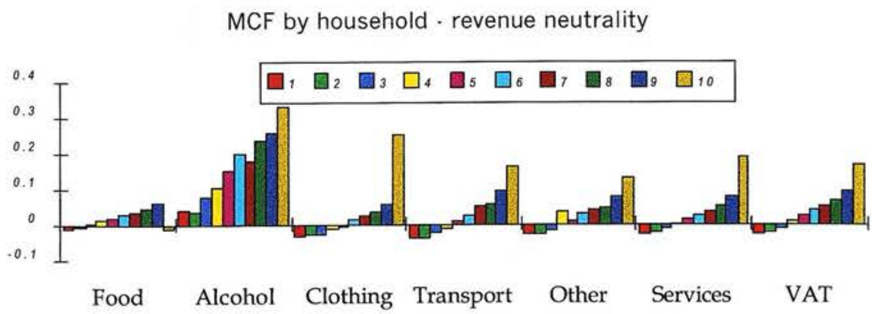


Figure 3.4d - MCF for revenue neutral tax changes in MiST model

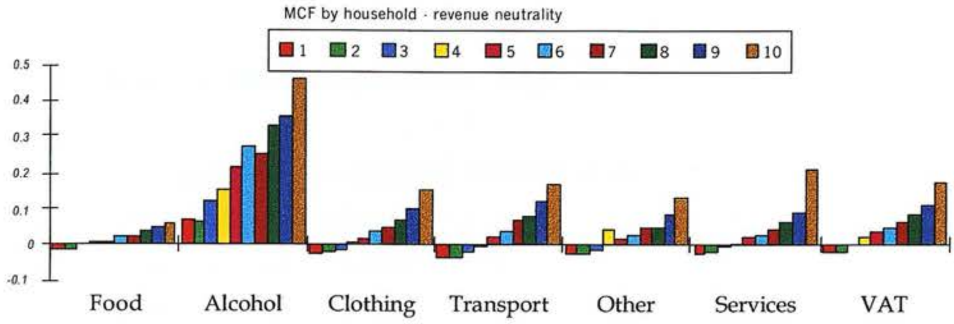


Figure 3.4e - MCF for revenue neutral tax changes in MiTS model

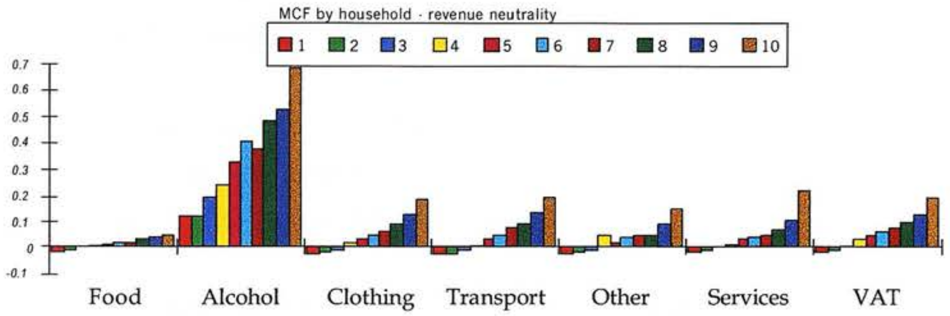
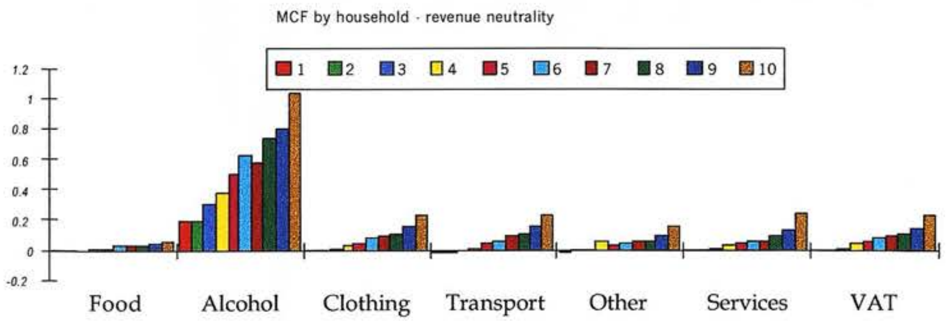


Figure 3.4f - MCF for revenue neutral tax changes in MiTT model



The basic pattern is that for all goods, with the exception of Alcohol, a revenue-neutral tax change causes a direct welfare loss to the lower end of the income spectrum. This loss is least for Food. This means that the second dividend exists in it's strong form for Alcohol and it's weak form for all other goods. In general the Macro models tend to understate the gains for the high income households and overstate the losses of the low income households.

This is due to the fact that the MCF for Fuel is significantly higher in the Macro models.

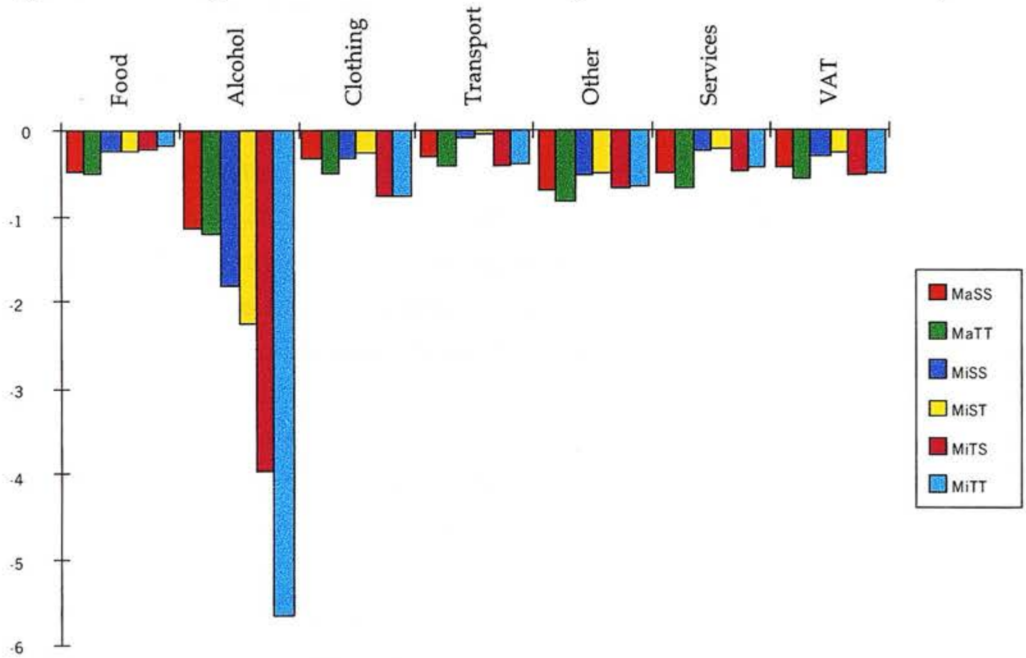
The values for the MED are shown in Table 3.6.

Table 3.6 - Marginal Environmental damage under revenue-neutrality.

MED	Food	Alcohol	Clothing	Transport	Other	Services	VAT
MaSS	-0.47994	-1.13067	-0.33599	-0.29579	-0.69661	-0.48825	-0.43407
MaTT	-0.49128	-1.19949	-0.49151	-0.40725	-0.82577	-0.68766	-0.55679
MiSS	-0.24292	-1.80569	-0.31859	-0.10446	-0.52021	-0.23666	-0.28638
MiST	-0.22945	-2.24268	-0.27696	-0.04793	-0.49121	-0.20612	-0.25541
MiTS	-0.20942	-3.96773	-0.75392	-0.41315	-0.66958	-0.48103	-0.53079
MiTT	-0.18579	-5.64812	-0.75121	-0.38025	-0.63856	-0.45641	-0.50605

The table clearly shows that what ever the revenue returning instrument, the environment clearly benefits. However the scale of this benefit varies considerably. This is illustrated in Figure 3.5.

Figure 3.5 - Marginal Environmental Damages under revenue-neutrality



Reducing taxes on Alcohol yields the greatest environmental benefit. Indeed, given the direct benefit from using Alcohol tax, the strongest policy prescription is to use the revenue raised from the tax on Fuel to reduce taxes on Alcohol. This raises several policy issues. Firstly, alcohol and tobacco are considered by many (but not all) to be 'bad' goods and responsible for externalities in their own right and there would likely be objections on health and perhaps, public order grounds. Secondly though, in a European context, taxes on Alcohol and Tobacco are significantly higher in Britain than much of Continental Europe and thus there may be scope for implementation in a European context.

The overall effect of tax changes depends on both the direct and environmental effect. The difficulty in quantifying environmental benefits in monetary terms means that no exact values for this combination, the marginal social cost of funds, are given here. What is important however, is the fact that the environment improves under **any** of the tax changes and the MED estimates reflect the magnitude of this benefit. The marginal environmental valuation of households is however important in considering distributional issues and this is dealt with in the following section.

3.4.4 Distributional issues

The previous section showed that lower income households face a direct welfare loss in all cases except that of a reduction in Alcohol taxes. However, the tax changes may still be Pareto improving if the environmental benefit of the changes offsets this direct loss. To this end, critical values of the marginal environment value required by each household so that they are made no worse off were calculated and are given in Appendix 2e. A household whose welfare directly improves does not 'need' to value the environment and so values are not reported for these households[5]. It should be remembered that all values are in terms of the income of the lowest household.

These critical values are highest for household 1 in all cases except transport. Examination of the critical values for transport shows them to be extremely high - household 1 would have to place a marginal value on the environment equal to around 70% of its expenditure. This is due to the fact that the environmental improvement using Transport as a revenue redistributive instrument is very small. The other goods give more realistic values and the highest required environmental valuations are reported in Table 2.7.

Table 3.7 - Highest critical values for Marginal Environmental Valuation across all models

Clean Good	Food	Clothing	Transport	Other	Services	VAT
Critical MEV	0.050462	0.126803	0.655142	0.055195	0.128692	0.097914

These are the 'worst case' values across all models. The equity change equation, equation (3.19) is not applied at this point as the fact that some households lose and some gain directly coupled with the difficulty in quantifying the value of the environmental effects mean it is somewhat meaningless. For example, suppose household 1 placed a marginal valuation of 9.79% of its non-durable expenditure, on the environment. In this case, it's welfare would be unchanged if VAT was used as the revenue redistributive instrument. If all households valued the environment the same then they would all benefit the same from the environmental improvement. This is unlikely to be the case, in reality. However, as a demonstration it will be assumed it is. The MiSS model that this critical value is associated with is now examined. Table 2.8 shows the application of equation (3.19) to this scenario. The adjusted figure shows the welfare change of each household is dividend by its expenditure[6].

Table 3.8 - Welfare Change in MiSS model with MEV of all households equal to critical MEV for household 1.

Welfare Change	0.00%	0.31%	1.68%	3.68%	5.08%	6.61%	7.90%	9.19%	12.00 %	19.65 %
Adjusted	0.00%	0.25%	0.91%	1.57%	1.72%	1.99%	2.22%	2.13%	2.23%	2.64%

Thus in this case the impact is relatively regressive. What is more interesting is to examine the MEV's required in order that all households receive the same proportional welfare change. This is shown in the Table 2.9.

Table 3.9 - Required MEV of households to achieve same proportional welfare change.

	Required MEV of Household									
Proportional Welfare Change	1	2	3	4	5	6	7	8	9	10
2.26%	0.177	0.186	0.184	0.155	0.153	0.130	0.104	0.118	0.103	0.000
2.5%	0.185	0.197	0.200	0.174	0.178	0.158	0.133	0.154	0.148	0.062
3%	0.203	0.218	0.232	0.215	0.230	0.216	0.196	0.229	0.242	0.192
4%	0.238	0.262	0.296	0.297	0.333	0.332	0.320	0.380	0.430	0.452
5%	0.273	0.306	0.360	0.379	0.436	0.448	0.445	0.531	0.617	0.712
10%	0.447	0.525	0.681	0.788	0.951	1.029	1.068	1.285	1.556	2.012

A proportional welfare increase of 2.26% is the smallest achievable by household 10 without a non-positive environmental valuation. What is interesting is that as the proportional welfare changes become higher, there is a switch between lower income households having to value the environment more and higher income households having to. The higher proportional changes are achieved by all households valuing the environment more, but what is important is that lower income have to value the environment less highly than higher income households.

This tentative result can be interpreted as follows: the higher environmental valuation generally, then the less regressive is revenue neutral tax reform. More strongly, if environmental valuation is generally high then the firm possibility arises that the tax reform may in fact be equity improving whilst still Pareto improving i.e. everyone is made better off, but lower income groups gain proportionally more. Intuitively, lower income households benefit from the reduction in environmentally damaging consumption of higher income households. This reduction in consumption is proportionally less for the higher income households, hence they benefit directly, but the indirect benefit is felt proportionally more by those on a low income[7]. This must be qualified however by the fact, that in this particular scenario, 'high' environmental valuation represents some 20% of the income of the lowest income household.

3.5 Conclusions

This chapter has defined a measure, the marginal social cost of public funds, that allows the traditional idea of the double dividend to be analysed from three different angles - the direct impact, the environmental impact and the distributional impact. The analysis is conducted in a partial equilibrium framework. However, no firm conclusions can be drawn on any of these measures from a theoretical analysis, but it is possible to suggest what may happen.

Firstly, the environmental dividend may not necessarily be positive. This is due to the fact that the complex relationships between goods may mean that by redistributing the revenue from the tax on the environmentally destructive good, the reduction in other taxes may result in the consumption of the externality producing good increasing.

Secondly, the second dividend may not exist in its strong form in that the efficiency of the whole tax system improves. Increasing the tax rate on a narrow base good and reducing the tax on a broad base may increase the existing inefficiency in the tax system. This does not prevent the weak second dividend from existing. Indeed the theory outlined suggests it will always exist. These points are consistent with earlier work.

These effects cannot be determined by theoretical analysis alone, rather empirical analysis is needed. The simple small, open economy model is set up empirically and the effects of changes in the taxation of consumption of non-durables, analysed. The results show that the environmental dividend is always positive but the magnitude of this dividend depends very strongly on the revenue redistribution instrument.

The empirical analysis shows that the strong form of the second dividend exists only when externality tax revenue is used to reduce the tax rate on Alcohol and Tobacco. However, the weak form holds in all cases. Lower income households face a direct welfare decrease under all alternate tax change options but less than without revenue-neutrality. Thus, lower income household require positive environmental valuation in order to be better off.

The most interesting result however, is that equity may be improved, or in other words the tax changes are progressive, if environmental valuation is high.

Appendix 3a - Pashardes (1993) Results

MacroStone	Food	Alcohol	Fuel	Clothing	Trans.	Other	Services
Intercept	0.6417	0.0866	0.2275	0.079	0.0913	0.1085	-0.2344
LogEx	-0.0715	-0.0034	-0.0398	0.0193	0.0187	0.0015	0.0751
Food	0.1175	0.0013	-0.0096	-0.0397	-0.0117	-0.0576	0
Alcohol	0.0013	-0.0272	0.0294	0.0142	0.0244	-0.0306	-0.0114
Fuel	-0.0096	0.0294	0.0241	-0.0164	-0.0449	0.0235	-0.006
Clothing	-0.0397	0.0142	-0.0164	0.0785	-0.0551	0.0541	-0.0356
Transport	-0.0117	0.0244	-0.0449	-0.0551	0.0748	-0.008	0.0207
Other	-0.0576	-0.0306	0.0235	0.0541	-0.008	0.0248	-0.0063
Services	0	-0.0114	-0.006	-0.0356	0.0207	-0.0063	0.0392

MacroTrue	Food	Alcohol	Fuel	Clothing	Trans.	Other	Services
Intercept	0.6458	0.0884	0.2383	0.0727	0.0861	0.0825	-0.2139
LogEx	-0.0724	-0.0038	-0.0423	0.0208	0.0199	0.0076	0.0701
Food	0.0788	-0.0013	-0.036	-0.0279	-0.0026	-0.0509	0.0377
Alcohol	-0.0013	-0.0268	0.0271	0.0152	0.0253	-0.0305	-0.0089
Fuel	-0.036	0.0271	0.0095	-0.0088	-0.0401	0.0278	0.0182
Clothing	-0.0279	0.0152	-0.0088	0.0751	-0.0573	0.0515	-0.0477
Transport	-0.0026	0.0253	-0.0401	-0.0573	0.0719	-0.0086	0.0116
Other	-0.0509	-0.0305	0.0278	0.0515	-0.0086	0.023	-0.0124
Services	0.0377	-0.0089	0.0182	-0.0477	0.0116	-0.0124	0.0019

MicStone	Food	Alcohol	Fuel	Clothing	Trans.	Other	Services
Intercept	0.5318	0.0052	0.1388	-0.0026	0.1595	0.0933	0.074
LogEx	-0.1385	0.0435	-0.0675	0.0446	0.0925	-0.0079	0.0333
Food	-0.0576	0.063	-0.0946	0.0343	0.0558	-0.0566	0.0557
Alcohol	0.063	-0.077	0.0738	-0.0019	-0.0172	-0.0213	-0.0194
Fuel	-0.0946	0.0738	0.0091	0.0172	-0.0188	0.0204	-0.0071
Clothing	0.0343	-0.0019	0.0172	0.0105	-0.0525	0.0422	-0.0498
Transport	0.0558	-0.0172	-0.0188	-0.0525	0.0266	-0.0026	0.0087
Other	-0.0566	-0.0211	0.0204	0.0422	-0.0026	0.0165	0.0012
Services	0.0557	-0.0194	-0.0071	-0.0499	0.0087	0.0011	0.0109

MicTrue	Food	Alcohol	Fuel	Clothing	Trans.	Other	Services
Intercept	0.5318	0.0052	0.1388	-0.0026	0.1595	0.0933	0.074
LogEx	-0.1385	0.0435	-0.0675	0.0446	0.0925	-0.0079	0.0333
Food	-0.0576	0.063	-0.0946	0.0343	0.0558	-0.0566	0.0557
Alcohol	0.063	-0.077	0.0738	-0.0019	-0.0172	-0.0213	-0.0194
Fuel	-0.0946	0.0738	0.0091	0.0172	-0.0188	0.0204	-0.0071
Clothing	0.0343	-0.0019	0.0172	0.0105	-0.0525	0.0422	-0.0498
Transport	0.0558	-0.0172	-0.0188	-0.0525	0.0266	-0.0026	0.0087
Other	-0.0566	-0.0211	0.0204	0.0422	-0.0026	0.0165	0.0012
Services	0.0557	-0.0194	-0.0071	-0.0499	0.0087	0.0011	0.0109

Appendix 3b - Calibrated Parameters

MaSS

Household	Average	1	2	3	4	5	6	7	8	9	10
I-Food	0.349757	0.336685	0.342335	0.347358	0.327523	0.330645	0.335305	0.327324	0.372534	0.3456	0.339788
I-Alcohol	0.101112	0.120019	0.100986	0.105089	0.096025	0.103679	0.109079	0.096326	0.100972	0.091721	0.085824
I-Fuel	0.105194	0.123287	0.114555	0.10252	0.089151	0.093126	0.088816	0.0847	0.091264	0.094036	0.101349
I-Clothing	0.042868	0.047298	0.054606	0.043348	0.046678	0.043326	0.048052	0.046653	0.046985	0.044731	0.038545
I-Transport	0.146179	0.097617	0.089262	0.131231	0.122706	0.16458	0.16513	0.19393	0.148737	0.189285	0.16971
I-Other	0.127775	0.100581	0.106231	0.109667	0.185304	0.123966	0.129789	0.133681	0.123396	0.133065	0.132578
I-Services	0.127114	0.174513	0.192025	0.160786	0.132612	0.140679	0.123829	0.117386	0.116113	0.101561	0.132206

MaST

Household	Average	1	2	3	4	5	6	7	8	9	10
I-Food	0.280744	0.072408	0.510051	0.495917	-0.30663	-0.31963	0.474021	0.378369	1.094396	-0.34663	0.38108
I-Alcohol	0.09783	0.107452	0.107786	0.112208	0.066757	0.072757	0.115734	0.098757	0.136758	0.058757	0.0877
I-Fuel	0.065782	-0.02298	0.208853	0.186775	-0.26385	-0.26885	0.167601	0.113154	0.510169	-0.29185	0.12431
I-Clothing	0.061495	0.119436	0.009334	0.002941	0.217855	0.218855	0.010275	0.032855	-0.15615	0.231855	0.02659
I-Transport	0.165155	0.166736	0.045398	0.09208	0.288561	0.335561	0.128683	0.180561	-0.01845	0.370561	0.1586
I-Other	0.129223	0.106125	0.102713	0.106527	0.198608	0.137608	0.126853	0.132608	0.107608	0.147608	0.13173
I-Services	0.19977	0.450827	0.015865	0.003553	0.798696	0.823696	-0.02317	0.063696	-0.67433	0.829696	0.08987
PIndex Co-ef	0.965673	3.655931	-2.322	-2.06871	8.784777	9.010259	-1.92781	-0.69719	-10.4053	9.611026	-0.5400

MaTS

Household	Average	1	2	3	4	5	6	7	8	9	10
I-Food	0.345833	0.331684	0.337544	0.342502	0.323288	0.326613	0.330144	0.323392	0.338152	0.343108	0.33758
I-Alcohol	0.100962	0.119388	0.100044	0.104702	0.096621	0.103478	0.108926	0.095870	0.101573	0.091761	0.08599
I-Fuel	0.104832	0.119915	0.111765	0.100671	0.087907	0.092445	0.089105	0.084495	0.091534	0.094857	0.10257
I-Clothing	0.042795	0.049832	0.055988	0.044167	0.047134	0.043444	0.047993	0.046485	0.046532	0.043948	0.03620
I-Transport	0.146969	0.098923	0.090289	0.131806	0.122990	0.165503	0.165158	0.193716	0.177934	0.188548	0.16809
I-Other	0.122391	0.102539	0.106769	0.107912	0.180782	0.119359	0.124463	0.127912	0.116468	0.124793	0.12232
I-Services	0.136219	0.177720	0.197601	0.168241	0.141278	0.149159	0.134211	0.128130	0.127808	0.112985	0.14662

MaTT

Household	Average	1	2	3	4	5	6	7	8	9	10
I-Food	-0.61374	0.143767	0.266883	0.873256	0.098052	0.090301	0.819256	0.083256	0.808256	0.059939	0.768256
I-Alcohol	0.050597	0.109525	0.095564	0.132597	0.084799	0.091075	0.134597	0.083597	0.125597	0.076898	0.108597
I-Fuel	-0.4558	0.010123	0.07135	0.411195	-0.04369	-0.04562	0.374195	-0.0558	0.366195	-0.07059	0.354195
I-Clothing	0.318474	0.103819	0.076289	-0.10853	0.111842	0.111334	-0.09253	0.115474	-0.08853	0.1253	-0.08753
I-Transport	0.41072	0.150574	0.109711	-0.01428	0.184899	0.230456	0.03072	0.25972	0.04872	0.26638	0.04972
I-Other	0.22312	0.122265	0.114187	0.05212	0.205716	0.144165	0.07312	0.15312	0.06712	0.154518	0.07712
I-Services	1.066637	0.359927	0.266017	-0.34636	0.358379	0.37829	-0.33936	0.360637	-0.32736	0.38755	-0.27036

MiSS

Household	Average	1	2	3	4	5	6	7	8	9	10
I-Food	0.422512	0.31901	0.342962	0.374786	0.374067	0.393943	0.406124	0.404692	0.433401	0.453535	0.386392
I-Alcohol	0.056611	0.14088	0.108027	0.092888	0.07157	0.066093	0.066095	0.048406	0.043732	0.021514	-0.00199
I-Fuel	0.121202	0.107155	0.104641	0.102646	0.095738	0.105733	0.104569	0.102389	0.114028	0.122684	0.13825
I-Clothing	0.028682	0.05634	0.058701	0.04075	0.039772	0.032407	0.035035	0.032346	0.029295	0.023119	0.07272
I-Transport	0.071455	0.112002	0.087229	0.100071	0.073445	0.099363	0.090344	0.113568	0.083798	0.078191	0.058662
I-Other	0.141299	0.097132	0.106066	0.115804	0.192853	0.135694	0.143179	0.148092	0.140487	0.153264	0.15735
I-Services	0.15824	0.167481	0.192375	0.173055	0.152553	0.166767	0.154653	0.150507	0.155259	0.147694	0.188619

MiST

Household	Average	1	2	3	4	5	6	7	8	9	10
I-Food	0.292683	0.160801	0.192492	0.25057	0.21579	0.249014	0.266706	0.270327	0.28988	0.307222	0.331428
I-Alcohol	0.101935	0.196461	0.160558	0.136586	0.126826	0.116689	0.113767	0.095161	0.093504	0.073175	0.048035
I-Fuel	0.061987	0.033539	0.03601	0.046657	0.024145	0.040079	0.041647	0.041258	0.048567	0.05519	0.073761
I-Clothing	0.062718	0.096852	0.096989	0.072358	0.080047	0.069285	0.070511	0.066536	0.065815	0.060773	0.046065
I-Transport	0.153712	0.213435	0.183724	0.179729	0.173349	0.190855	0.179752	0.199734	0.175837	0.173089	0.124541
I-Other	0.130079	0.083373	0.093063	0.10407	0.180175	0.12317	0.131131	0.136481	0.128084	0.140476	0.145131
I-Services	0.196885	0.214872	0.237165	0.21003	0.199667	0.210908	0.196153	0.190503	0.19798	0.191742	0.230706
PIndex Co-ef	0.894231	1.032256	0.984437	0.828069	1.062498	0.984533	0.953134	0.923228	0.991069	1.030139	1.000425

MiTS

Household	Average	1	2	3	4	5	6	7	8	9	10
I-Food	0.369585	0.274971	0.297224	0.325303	0.322818	0.341047	0.353368	0.351381	0.383397	0.397253	0.41317
I-Alcohol	0.080559	0.155921	0.124791	0.112434	0.092908	0.089099	0.088973	0.07282	0.068217	0.048966	0.027859
I-Fuel	0.103814	0.088563	0.086281	0.084663	0.077997	0.088217	0.087171	0.085064	0.096892	0.105769	0.121659
I-Clothing	0.034282	0.069967	0.070581	0.049811	0.047018	0.037962	0.039706	0.036473	0.031997	0.024168	0.008703
I-Transport	0.094815	0.134426	0.109886	0.125104	0.09772	0.122863	0.114962	0.137283	0.104347	0.102292	0.060293
I-Other	0.134338	0.095828	0.103668	0.110639	0.18855	0.129332	0.136263	0.140835	0.132337	0.144078	0.14664
I-Services	0.182608	0.180323	0.207569	0.192047	0.172989	0.191481	0.179556	0.176143	0.182814	0.177475	0.221676

MiTT

Household	Average	1	2	3	4	5	6	7	8	9	10
I-Food	0.244901	0.122187	0.152406	0.206173	0.171232	0.203285	0.218379	0.22112	0.239764	0.254874	0.283668
I-Alcohol	0.119438	0.203907	0.169961	0.14985	0.140518	0.131367	0.131056	0.113426	0.111885	0.093684	0.068532
I-Fuel	0.043847	0.013538	0.01619	0.027996	0.004119	0.021077	0.02187	0.022054	0.030653	0.036378	0.058545
I-Clothing	0.074143	0.11873	0.117894	0.088173	0.095832	0.082324	0.082854	0.078106	0.076425	0.070017	0.050406
I-Transport	0.177393	0.237466	0.205937	0.203274	0.198959	0.21587	0.20445	0.224604	0.200821	0.198383	0.145783
I-Other	0.127277	0.087114	0.095465	0.103844	0.179904	0.121474	0.12862	0.133461	0.124467	0.135956	0.139253
I-Services	0.213002	0.217058	0.242147	0.22069	0.210435	0.224603	0.211772	0.207228	0.215985	0.211708	0.252812
PIndex Co-ef	0.889967	1.03426	0.980758	0.824049	1.05885	0.972222	0.950085	0.920261	0.987712	1.027077	0.950311

Appendix 3c - MCF and MEI for all households

MaSS	Food	Alcohol	Fuel	Clothing	Transport	Other	Services	VAT
AV	0.104785	0.193875	0.11163	0.088246	0.092947	0.103702	0.102398	0.112865
1	0.040285	0.073332	0.06239	0.019785	0.016641	0.02394	0.024112	0.026743
2	0.048828	0.075387	0.068321	0.030018	0.02008	0.031858	0.036894	0.034876
3	0.066576	0.113833	0.078253	0.041365	0.043533	0.048438	0.053181	0.057332
4	0.074372	0.129937	0.076254	0.059434	0.054129	0.105407	0.064367	0.075554
5	0.088894	0.177063	0.089478	0.075831	0.089485	0.088669	0.092192	0.10129
6	0.098717	0.210773	0.087752	0.093716	0.102357	0.104875	0.099932	0.115027
7	0.100086	0.195057	0.083107	0.100475	0.126642	0.115926	0.106597	0.123471
8	0.137904	0.247685	0.098725	0.127731	0.125073	0.129805	0.137582	0.144928
9	0.143516	0.272395	0.108689	0.162737	0.193374	0.174668	0.172844	0.186274
10	0.172961	0.344379	0.132285	0.227134	0.253566	0.243301	0.303676	0.260815
MEI co-ef	-0.03682	0.613905	-0.51676	-0.18077	-0.22098	0.17985	-0.02851	-0.0827

MaST	Food	Alcohol	Fuel	Clothing	Transport	Other	Services	VAT
AV	0.101939	0.016596	0.112541	0.1056	0.081716	0.113004	0.16883	0.114009
1	0.191674	0.023984	0.072514	0.06826	0.097205	0.118382	0.192813	0.027075
2	0.101122	0.025362	0.042907	0.086452	0.102148	0.244879	0.174988	0.035118
3	0.091526	0.047502	0.043411	0.175046	0.105066	0.090644	0.183283	0.058004
4	0.093168	0.07356	0.048527	0.082073	0.105932	0.132468	0.169126	0.07642
5	0.103891	0.063191	0.056375	0.078675	0.097326	0.144765	0.340462	0.102364
6	0.108629	0.031136	0.07233	0.08966	0.192841	0.13004	0.122976	0.11621
7	0.039186	0.020024	0.129828	0.088832	0.076258	0.145808	0.232662	0.124466
8	0.072499	0.031917	0.069948	0.09776	0.104218	0.140202	0.252239	0.151014
9	0.057604	0.039108	0.061663	0.095539	0.126283	0.269291	0.243746	0.187225
10	0.020819	0.064517	0.053983	0.20838	0.116137	0.099642	0.321902	0.260881
MEI co-ef	-4.2E-05	0.675279	-0.4439	-0.15216	-0.18216	0.219865	0.011503	-0.04399

MaTS	Food	Alcohol	Fuel	Clothing	Transport	Other	Services	VAT
AV	0.104187	0.01646	0.112339	0.105644	0.084742	0.109867	0.166242	0.113142
1	0.191329	0.024164	0.074741	0.066343	0.095736	0.120977	0.191233	0.02682
2	0.106612	0.024664	0.042258	0.088388	0.101318	0.246279	0.176299	0.03486
3	0.090149	0.048552	0.043058	0.174737	0.105855	0.094271	0.17699	0.057529
4	0.092414	0.074064	0.048892	0.085453	0.102997	0.130482	0.172874	0.075746
5	0.104671	0.065259	0.054813	0.077467	0.099484	0.143601	0.339842	0.101555
6	0.104846	0.030665	0.073949	0.088923	0.191717	0.131017	0.124979	0.115485
7	0.040057	0.019862	0.129598	0.089498	0.079359	0.141801	0.229158	0.123736
8	0.07237	0.032156	0.072826	0.094414	0.102639	0.143349	0.250195	0.1505
9	0.059595	0.038026	0.060716	0.097654	0.125256	0.268818	0.245634	0.186197
10	0.020501	0.066109	0.053538	0.208007	0.117008	0.103778	0.312942	0.259486
MEI co-ef	-0.1373	0.558466	-0.68498	-0.09907	-0.19518	0.214734	0.089117	-0.04943

MaTT	Food	Alcohol	Fuel	Clothing	Transport	Other	Services	VAT
AV	0.100249	0.1894	0.098796	0.093279	0.093714	0.10549	0.110898	0.114854
1	0.038547	0.071642	0.055245	0.021215	0.016693	0.024353	0.025962	0.027339
2	0.046722	0.072689	0.060918	0.031729	0.020143	0.032408	0.039954	0.035394
3	0.063469	0.111211	0.069296	0.043713	0.04366	0.049272	0.05758	0.058426
4	0.071153	0.128292	0.067479	0.062825	0.054293	0.107219	0.06934	0.076796
5	0.085045	0.172977	0.079177	0.080157	0.090173	0.090198	0.099366	0.102891
6	0.093983	0.205918	0.077679	0.09903	0.102733	0.106678	0.108198	0.116735
7	0.095717	0.190553	0.073516	0.106201	0.127014	0.117923	0.115449	0.125096
8	0.116427	0.241977	0.087381	0.134972	0.145606	0.132035	0.148961	0.151751
9	0.137918	0.266105	0.0961	0.172006	0.193916	0.177678	0.186323	0.187719
10	0.166361	0.336426	0.115819	0.237049	0.25369	0.247544	0.328732	0.260474
MEI co-ef	-0.07893	0.629277	-0.57021	-0.07871	-0.16296	0.255552	0.117447	-0.01342

MiSS	Food	Alcohol	Fuel	Clothing	Transport	Other	Services	VAT
AV	0.113362	0.249559	0.097306	0.081118	0.090574	0.102984	0.101587	0.11246
1	0.04345	0.094391	0.054376	0.018695	0.016128	0.023774	0.02392	0.026335
2	0.052825	0.095775	0.059547	0.027966	0.019652	0.031637	0.036601	0.034592
3	0.07175	0.146527	0.068207	0.038538	0.042198	0.048548	0.052759	0.05692
4	0.08046	0.169042	0.066469	0.055371	0.052468	0.104109	0.063856	0.075183
5	0.096173	0.227915	0.077999	0.070647	0.087156	0.088055	0.091018	0.100801
6	0.106255	0.274163	0.076497	0.087309	0.099304	0.104149	0.099139	0.11453
7	0.108248	0.251083	0.072453	0.093606	0.122772	0.115122	0.105752	0.123455
8	0.131634	0.32253	0.086071	0.118998	0.140751	0.128905	0.136493	0.149972
9	0.155268	0.350641	0.094762	0.151612	0.187441	0.173458	0.171476	0.186747
10	0.182016	0.445199	0.11377	0.362942	0.273962	0.241479	0.301087	0.282262
MEI co-ef	-0.1116	1.451169	-0.35453	-0.03594	-0.25007	0.165688	-0.11787	-0.06814

MiST	Food	Alcohol	Fuel	Clothing	Transport	Other	Services	VAT
AV	0.096406	0.313	0.086918	0.101011	0.099131	0.101539	0.104706	0.121344
1	0.03701	0.118566	0.048159	0.023022	0.017696	0.023429	0.024678	0.028606
2	0.044856	0.120356	0.0531	0.034424	0.0217	0.031181	0.037754	0.03769
3	0.060918	0.184772	0.061207	0.047443	0.046545	0.047409	0.054421	0.061718
4	0.068294	0.212458	0.059669	0.068151	0.05725	0.103186	0.065872	0.081494
5	0.081622	0.286404	0.069893	0.08695	0.095368	0.08679	0.094338	0.108551
6	0.090176	0.34089	0.068826	0.107439	0.109476	0.102654	0.10226	0.122551
7	0.091854	0.314998	0.064618	0.115187	0.135315	0.113471	0.109082	0.131884
8	0.111702	0.40378	0.076535	0.146421	0.155143	0.127052	0.140782	0.159669
9	0.132749	0.440795	0.084211	0.186543	0.206586	0.17097	0.176863	0.198691
10	0.159216	0.565152	0.101013	0.257412	0.270798	0.238015	0.310497	0.278043
MEI co-ef	-0.03215	1.981076	-0.2616	0.015364	-0.21367	0.229609	-0.05548	-0.00619

MiTS	Food	Alcohol	Fuel	Clothing	Transport	Other	Services	VAT
AV	0.089083	0.434153	0.07997	0.110374	0.104062	0.101507	0.108535	0.127668
1	0.034132	0.164216	0.0447	0.025102	0.018494	0.023439	0.025637	0.030034
2	0.0415	0.166619	0.048948	0.037546	0.022529	0.031191	0.039227	0.039594
3	0.056189	0.254911	0.056062	0.051742	0.049158	0.047421	0.056545	0.065036
4	0.063007	0.294081	0.054627	0.074338	0.060721	0.103145	0.068061	0.086107
5	0.075309	0.396504	0.064099	0.094847	0.100328	0.086795	0.098024	0.114005
6	0.083549	0.471997	0.062859	0.117211	0.114904	0.102654	0.106253	0.128111
7	0.085122	0.4368	0.059531	0.125663	0.141436	0.113466	0.11334	0.13812
8	0.105615	0.552489	0.070717	0.15975	0.159558	0.127061	0.146286	0.166099
9	0.122134	0.609994	0.077851	0.203531	0.215923	0.170963	0.183779	0.207963
10	0.147008	0.774004	0.09344	0.280979	0.285572	0.238052	0.322618	0.291196
MEI co-ef	-0.30749	3.450824	-0.51691	0.237012	-0.10376	0.152675	-0.03587	0.013884

MiTT	Food	Alcohol	Fuel	Clothing	Transport	Other	Services	VAT
AV	0.083784	0.616397	0.073269	0.120881	0.111751	0.100662	0.11147	0.133789
1	0.032078	0.234075	0.040408	0.027503	0.020242	0.023225	0.026304	0.031727
2	0.038874	0.237735	0.044393	0.042	0.024434	0.030907	0.040232	0.041929
3	0.052781	0.363629	0.051497	0.057071	0.052663	0.046991	0.057995	0.068245
4	0.059142	0.419737	0.049346	0.081931	0.065664	0.102243	0.070202	0.090797
5	0.070669	0.559458	0.057864	0.104524	0.108882	0.086016	0.100525	0.119181
6	0.078069	0.673233	0.056657	0.129097	0.124051	0.101736	0.108971	0.133279
7	0.079503	0.623514	0.053569	0.138407	0.153256	0.112454	0.116241	0.143708
8	0.096684	0.791535	0.064862	0.1759	0.175745	0.12592	0.150013	0.173791
9	0.114526	0.871114	0.069911	0.224077	0.233966	0.169437	0.188459	0.215866
10	0.137703	1.105975	0.083699	0.309361	0.306742	0.235927	0.330719	0.301277
MEI co-ef	-0.23525	5.227079	-0.42104	0.330172	-0.04079	0.217513	0.03537	0.085004

Appendix 3d - MCF and MEI for revenue-neutral tax changes

MaSS	Food	Alcohol	Clothing	Transport	Other	Services	VAT
AV	-0.00684	0.082245	-0.02338	-0.01868	-0.00793	-0.00923	0.001235
1	-0.0221	0.010942	-0.0426	-0.04575	-0.03845	-0.03828	-0.03565
2	-0.01949	0.007067	-0.0383	-0.04824	-0.03646	-0.03143	-0.03345
3	-0.01168	0.03558	-0.03689	-0.03472	-0.02981	-0.02507	-0.02092
4	-0.00188	0.053683	-0.01682	-0.02212	0.029154	-0.01189	-0.0007
5	-0.00058	0.087584	-0.01365	6.66E-06	-0.00081	0.002714	0.011811
6	0.010965	0.123022	0.005965	0.014605	0.017124	0.01218	0.027275
7	0.016978	0.11195	0.017367	0.043534	0.032818	0.02349	0.040363
8	0.039178	0.14896	0.029006	0.026348	0.031079	0.038857	0.046203
9	0.034826	0.163705	0.054047	0.084685	0.065979	0.064155	0.077585
10	0.040676	0.212094	0.094849	0.121281	0.111016	0.171391	0.12853

MaTT	Food	Alcohol	Clothing	Transport	Other	Services	VAT
AV	0.001453	0.090604	-0.00552	-0.00508	0.006693	0.012102	0.016058
1	-0.0167	0.016397	-0.03403	-0.03855	-0.03089	-0.02928	-0.02791
2	-0.0142	0.011771	-0.02919	-0.04078	-0.02851	-0.02096	-0.02552
3	-0.00583	0.041914	-0.02558	-0.02564	-0.02002	-0.01172	-0.01087
4	0.003674	0.060813	-0.00465	-0.01319	0.039741	0.001861	0.009318
5	0.005867	0.0938	0.00098	0.010996	0.011021	0.020189	0.023714
6	0.016304	0.128239	0.021351	0.025054	0.028998	0.030519	0.039056
7	0.022201	0.117037	0.032685	0.053498	0.044407	0.041933	0.05158
8	0.029047	0.154597	0.047592	0.058225	0.044655	0.06158	0.06437
9	0.041818	0.170005	0.075906	0.097816	0.081578	0.090223	0.091619
10	0.050543	0.220607	0.12123	0.137871	0.131725	0.212913	0.144655

MiSS	Food	Alcohol	Clothing	Transport	Other	Services	VAT
AV	0.016056	0.152253	-0.01619	-0.00673	0.005678	0.004281	0.015154
1	-0.01093	0.040015	-0.03568	-0.03825	-0.0306	-0.03046	-0.02804
2	-0.00672	0.036229	-0.03158	-0.03989	-0.02791	-0.02295	-0.02495
3	0.003543	0.07832	-0.02967	-0.02601	-0.01966	-0.01545	-0.01129
4	0.013991	0.102573	-0.0111	-0.014	0.03764	-0.00261	0.008714
5	0.018174	0.149917	-0.00735	0.009157	0.010056	0.013019	0.022802
6	0.029758	0.197666	0.010812	0.022807	0.027652	0.022642	0.038033
7	0.035794	0.17863	0.021152	0.050319	0.042669	0.033298	0.051002
8	0.045563	0.236459	0.032927	0.05468	0.042834	0.050422	0.063901
9	0.060505	0.255878	0.05685	0.092679	0.078696	0.076713	0.091984
10	-0.01175	0.331429	0.249172	0.160192	0.127709	0.187317	0.168491

MiST	Food	Alcohol	Clothing	Transport	Other	Services	VAT
AV	0.009489	0.226082	0.014093	0.012213	0.014621	0.017788	0.034426
1	-0.01115	0.070407	-0.02514	-0.03046	-0.02473	-0.02348	-0.01955
2	-0.00824	0.067257	-0.01868	-0.0314	-0.02192	-0.01535	-0.01541
3	-0.00029	0.123565	-0.01376	-0.01466	-0.0138	-0.00679	0.000511
4	0.008625	0.152789	0.008482	-0.00242	0.043517	0.006203	0.021825
5	0.011729	0.216511	0.017057	0.025475	0.016896	0.024445	0.038658
6	0.02135	0.272064	0.038613	0.040649	0.033828	0.033434	0.053725
7	0.027237	0.25038	0.050569	0.070697	0.048853	0.044464	0.067266
8	0.035167	0.327244	0.069885	0.078608	0.050517	0.064247	0.083134
9	0.048538	0.356585	0.102332	0.122375	0.08676	0.092653	0.11448
10	0.058204	0.464139	0.156399	0.169785	0.137003	0.209484	0.17703

MiTS	Food	Alcohol	Clothing	Transport	Other	Services	VAT
AV	0.009113	0.354183	0.030404	0.024092	0.021537	0.028565	0.047698
1	-0.01057	0.119516	-0.0196	-0.02621	-0.02126	-0.01906	-0.01467
2	-0.00745	0.117671	-0.0114	-0.02642	-0.01776	-0.00972	-0.00935
3	0.000127	0.198849	-0.00432	-0.0069	-0.00864	0.000483	0.008974
4	0.008381	0.239454	0.019711	0.006094	0.048519	0.013434	0.03148
5	0.011211	0.332406	0.030749	0.036229	0.022697	0.033926	0.049906
6	0.02069	0.409139	0.054352	0.052045	0.039795	0.043394	0.065252
7	0.025591	0.377269	0.066132	0.081905	0.053935	0.053809	0.078589
8	0.034898	0.481772	0.089033	0.088841	0.056343	0.075568	0.095381
9	0.044283	0.532143	0.12568	0.138072	0.093112	0.105927	0.130112
10	0.053568	0.680565	0.18754	0.192133	0.144612	0.229178	0.197757

MiTT	Food	Alcohol	Clothing	Transport	Other	Services	VAT
AV	0.010515	0.543127	0.047612	0.038482	0.027393	0.038201	0.06052
1	-0.00833	0.193667	-0.01291	-0.02017	-0.01718	-0.0141	-0.00868
2	-0.00552	0.193343	-0.00239	-0.01996	-0.01349	-0.00416	-0.00246
3	0.001284	0.312133	0.005574	0.001167	-0.00451	0.006498	0.016748
4	0.009796	0.370391	0.032585	0.016318	0.052896	0.020856	0.041451
5	0.012806	0.501595	0.04666	0.051019	0.028152	0.042662	0.061317
6	0.021412	0.616576	0.07244	0.067394	0.045079	0.052315	0.076622
7	0.025934	0.569944	0.084838	0.099687	0.058885	0.062672	0.090139
8	0.031823	0.726674	0.111039	0.110883	0.061058	0.085151	0.10893
9	0.044615	0.801203	0.154166	0.164056	0.099526	0.118548	0.145955
10	0.054005	1.022276	0.225663	0.223043	0.152228	0.24702	0.217578

MEI coefficients for revenue-neutral tax change

MiTT	Food	Alcohol	Clothing	Transport	Other	Services	VAT
MaSS	-0.47994	-1.13067	-0.33599	-0.29579	-0.69661	-0.48825	-0.43407
MaTT	-0.49128	-1.19949	-0.49151	-0.40725	-0.82577	-0.68766	-0.55679
MiSS	-0.24292	-1.80569	-0.31859	-0.10446	-0.52021	-0.23666	-0.28638
MiST	-0.22945	-2.24268	-0.27696	-0.04793	-0.49121	-0.20612	-0.25541
MiTS	-0.20942	-3.96773	-0.75392	-0.41315	-0.66958	-0.48103	-0.53079
MiTT	-0.18579	-5.64812	-0.75121	-0.38025	-0.63856	-0.45641	-0.50605

Appendix 3e - Critical values of MEV

MaSS	Food	Clothing	Transport	Other	Services	VAT
AV	0.014261	0.069595	0.063161	0.01138	0.018908	N/A
1	0.046057	0.126803	0.154667	0.055195	0.078398	0.082123
2	0.040614	0.114	0.163093	0.052343	0.064367	0.077051
3	0.024329	0.109787	0.117379	0.042799	0.05135	0.048198
4	0.003921	0.050059	0.0748	-0.04185	0.024345	0.001611
5	0.001217	0.040617	N/A	0.001161	-0.00556	N/A

MaTT	Food	Clothing	Transport	Other	Services	VAT
AV	N/A	0.011226	0.01248	N/A	N/A	N/A
1	0.033988	0.069236	0.094662	0.03741	0.042583	0.050119
2	0.028895	0.059386	0.100123	0.034526	0.030486	0.045842
3	0.011862	0.05205	0.06295	0.02425	0.017038	0.019523
4	-0.00748	0.009469	0.032378	N/A	N/A	N/A

MiSS	Food	Clothing	Transport	Other	Services	VAT
AV	N/A	0.050811	0.064445	N/A	N/A	N/A
1	0.044976	0.111995	0.366156	0.058826	0.128692	0.097914
2	0.027669	0.099128	0.381928	0.053649	0.096957	0.087136
3	N/A	0.093128	0.248991	0.037789	0.065275	0.039412
4	N/A	0.034837	0.134044	N/A	0.011041	N/A
5	N/A	0.023075	N/A	N/A	N/A	N/A

MiST	Food	Clothing	Transport	Other	Services	VAT
AV	N/A	N/A	N/A	N/A	N/A	N/A
1	0.048592	0.090759	0.635611	0.050345	0.113921	0.076556
2	0.035926	0.067429	0.655142	0.044622	0.074449	0.060333
3	0.001259	0.049694	0.305921	0.028089	0.03292	N/A
4	N/A	N/A	0.050474	N/A	N/A	N/A

MiTS	Food	Clothing	Transport	Other	Services	VAT
AV	N/A	N/A	N/A	N/A	N/A	N/A
1	0.050462	0.025994	0.063429	0.031752	0.039629	0.02763
2	0.035564	0.015124	0.063946	0.02652	0.020208	0.017622
3	N/A	0.00573	0.01671	0.012905	N/A	N/A

MiTT	Food	Clothing	Transport	Other	Services	VAT
AV	N/A	N/A	N/A	N/A	N/A	N/A
1	0.044835	0.017179	0.053034	0.026909	0.030901	0.017154
2	0.029703	0.003185	0.052489	0.02112	0.009116	0.004869

Notes:

[1]See Schöb (1995).
[2]Unless good d is a Giffen good - the quantity demanded rises as the price rises.
[3]Well founded suspicion as the next section will show.
[4] For the exact index model using micro data - the MITT model as defined here.
[5]In fact, a value can be calculated, but will be negative. This would give a measure of the extent to which the household would have to disvalue the environment in order to be left equally well off given the environmental improvement.
[6]In other words, expenditure is used as a proxy for welfare.
[7]Assuming a certain level of valuation.

Chapter 4 - Theoretical explanation of the Competitive General Equilibrium Model

This chapter explains the theoretical background to the competitive general equilibrium (CGE) model used in the next three chapters. This model builds significantly on the relatively simplistic general equilibrium model outlined in Chapter 3. The theoretical background to the model is complex, so the parameterisation and calibration of the model to its baseline scenario is explained separately in Chapter 5. The model, in common with most CGE models, generates a large set of results from each run. These results are dealt with in Chapter 6. This chapter does not detail the nature of the environmental taxes that will be imposed. This is dealt with in the relevant part of Chapter 6.

This chapter is divided into several sections, each dealing with a particular area of the model. Section 4.1 is an initial overview that details how the individual areas of the model link together and gives a brief description of each. The separate areas covered are Consumption (Section 4.2), Production (Section 4.3), Government (Section 4.4), Investment (Section 4.5), International Trade (Section 4.6) and Taxation (Section 4.7). Section 4.8 examines the solution procedure for the model and finally, Section 4.9 details the features of the model that make it especially suitable for its purpose - an examination of the distributional implications of revenue neutral tax reform.

4.1 Overview

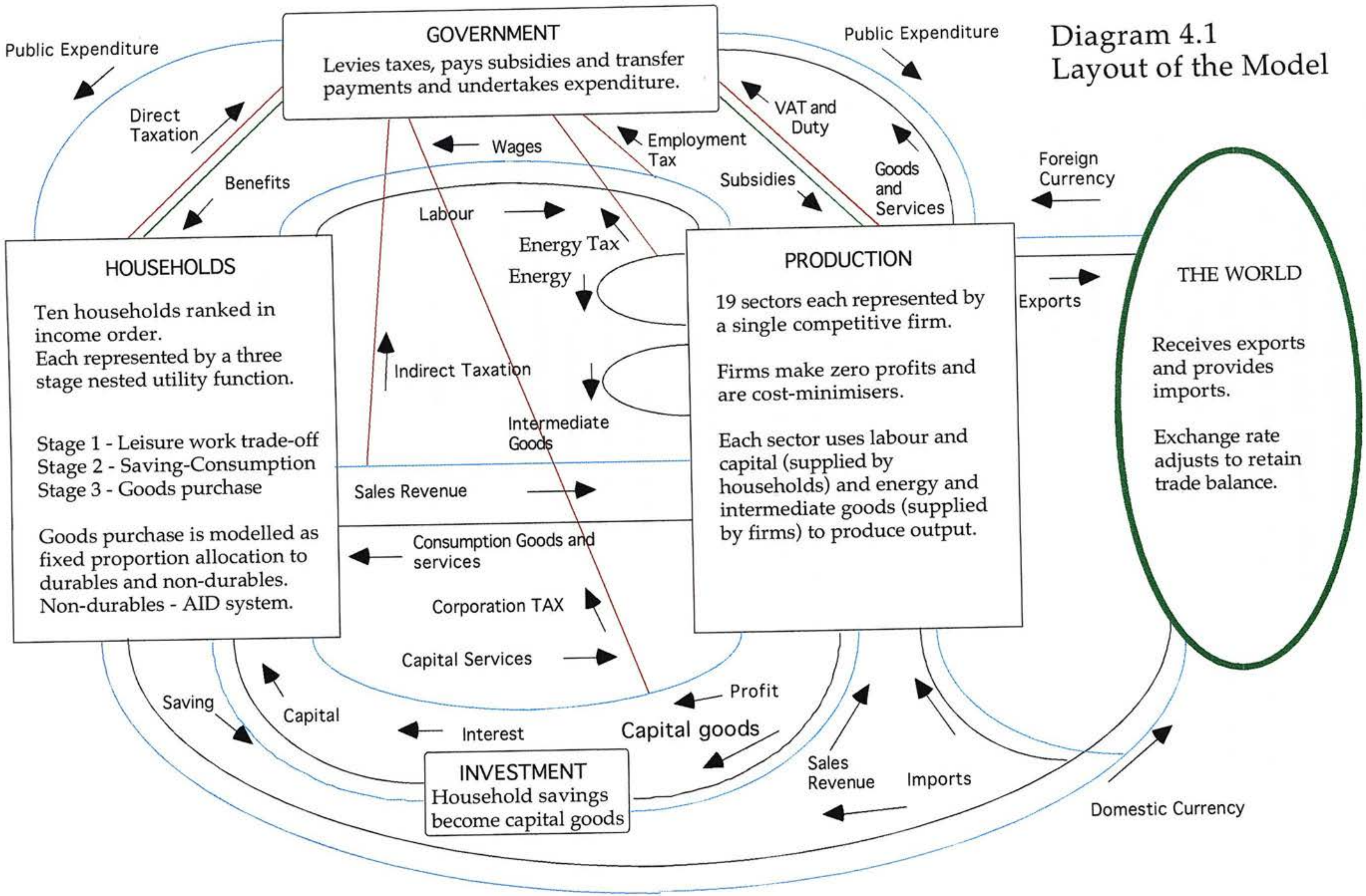
The model outlined in this chapter has been designed with a specific purpose in mind, namely the analysis of the distributional consequences of the double dividend hypothesis with particular regard to energy taxation. As such, the formulation of the model is geared to a clear exposition of this goal. The key feature that distinguishes it from an average or standard CGE model is the inclusion of different households with different resources and preferences. Further design features that aid this goal are detailed within the text, but are considered separately in Section 4.9. While the inclusion of multiple households is necessary for what is required it greatly adds to the complexity involved.

As mentioned in the introduction, the model is explained by breaking it down into areas - Households, Production, Government, Investment, Trade and Taxation. The first five of these represent sectors of the economy and the sixth, linkages, primarily between the other sectors and the government. However, there are numerous links between all the sectors. Due to this complexity, a diagram is useful to provide a general overview. See Diagram 4.1.

Diagram 4.1 shows the relationships and linkages between sectors of the economy in the model. Movements of goods and services, including factor services are shown by black lines, financial movements are shown by blue lines and taxation is shown in red. In addition financial movements from the government (transfer payments and subsidies) are shown in green. The diagram is somewhat stylised for simplicity - for example the production sector pays VAT and duty on its intermediate inputs, but this link is not shown directly.

There are ten households in the model who each supply labour and capital to the production sector. These households are differentiated by income and are ranked in income order. Household one represents the lowest decile of households by income and household ten the highest decile. Generally, the higher the income of a household the more labour and capital it will own and thus supply. This makes immediate sense when one regards capital but the larger supply of labour of higher income households may seem unintuitive. This may simply be accepted or labour can be thought of as being specified in terms of efficiency units rather than simply by time.

Diagram 4.1
Layout of the Model



Each household receives income from its factor services (wages from labour and interest from capital) and transfer payments from the government. Each household buys consumption goods (Food, Alcohol and Tobacco, Fuel, Clothing, Transport, Services and Other), which are fixed coefficient composites of the output of the production sector, from the production sector, receives the implicit benefit of government (public) expenditure and adds to savings. These savings are converted into capital goods by the investment process which then increases the capital stock, owned by households, in the following period. The production sector comprises 19 sectors as shown in Table 4.1. The conversion matrix between producer goods and consumer goods is detailed in the section on the production sector in Chapter 5.

The model is standard, in terms of general equilibrium models, in that it assumed that all sectors clear[1]. Indeed, the particular title used - Competitive General Equilibrium implies this. This is obvious for the commodities in the model (although does preclude the modelling of stocks and inventories) but has distinct implications for analysing the effect on the labour market. The approach used means that the labour market clears and there is no possibility of involuntary unemployment. This is an issue that is returned to in more detail in section 4.4.

The energy sectors are represented in Table 4.1 by bold and italic type. Each sector of production is represented by a single, perfectly competitive firm operating under constant returns to scale. Each sector makes normal profits at all times. Each sector uses the output of other sectors (including itself), in the form of intermediate goods, to produce its output. The intermediate good usage is given by a fixed co-efficient make matrix that gives the amount of intermediate inputs per unit output. In addition, labour, capital and energy appear directly in the firms production function. The inclusion of energy in the production function is to allow substitution between energy and labour/capital, when the price of energy changes (due to the imposition of a tax). The energy use of each sector is broken down into the five component energy types in a constant way.

Table 4.1 - Production sectors in the model

Alcohol and Tobacco	Government
Clothing	Household Durables
Durables	Other
Coal Extraction	Construction Materials
Oil and Gas Extraction	Services
Coke	Business Services
Oil Production	Transport
Electricity	Capital Goods
Gas	Raw Materials
Food	

Each sector must pay production taxes (duty etc.) to the government on its intermediate inputs if applicable, employment tax (National Insurance) on its labour inputs and Value Added Tax (VAT) on the excess of its output over its intermediate inputs. The firms payment to capital, its normal profit, is subject to corporation tax. Each sector also benefits implicitly from government expenditure, sells its output to both the private (consumption) and public sector (government) and may receive government subsidies directly. The output of each sector adjusts to fulfil the total demand for its product: Consumption (C) plus Investment (I) + Government Expenditure (G) + Intermediate Usage (U) + Exports (X) minus Imports (M).

International trade is modelled in the following way. The output of each sector may be both exported and imported[2]. The demand for exports depends on the price faced by external agents which is dependant on the domestic price and the exchange rate and the demand for imports on the price faced by domestic agents which will be dependant on the world price and the exchange rate. The exchange rate adjusts, in equilibrium, to preserve trade balance. Due to the difficulty in finding suitable data on the export and import price elasticity of substitution for the 19 production sectors, exports and imports are treated as fixed co-efficient composites of the output of the production sectors.

4.2 The Household Sector

As detailed in the overview, the household sector comprises ten distinct households, each with their own allocation of factors (labour and capital) and their own demand system parameters. The households each represent a particular decile of the income range, ranging from the lowest 10% (household 1) to the highest 10% (household 10). One feature of the model is that no allowance is made for a lower ranked household catching up or overtaking a higher ranked household. However, such is the distinction between the different groups, this is unlikely to happen. If it does it is not problematic, but simply means there has been an extremely large transference of resources.

The behaviour of the household sector as a whole is calculated simply by summing the behaviour of the individual household groups. This should be thought of as a 'multiple to single' approach. The structure that generates the behaviour of each household group is detailed below. This structure is the same for all households and the differences come from the parameterisation.

It is important to stress that the importance of the inclusion of multiple households cannot be overstated when dealing with distributional effects. Although this may appear obvious, it is possible to take the opposite approach to that used here, a 'single to multiple' approach. Instead of treating each household group as an entity in it own right and then summing the behaviour of these distinct entities to find the overall picture, it is possible to set up the model with a single household, calculate results and then disaggregate to smaller household groups. However, this approach, although much simpler analytically, would result in a much poorer analysis. This issue, along with a detailed discussion of those details of the household structure that enhance the capacity of the model in dealing with distributional considerations is dealt with in Section 4.9.

As all households groups have the same structure, references to household group have been dropped for simplicity. Details on which parameters are allowed to vary and which remain constant, between different households, can be found in Appendix 4 and are dealt with in the following chapter.

Each household is assumed to be Utility maximising and optimises a three-stage, nested utility function as shown in Diagram 4.2.

In the first stage they allocate expanded or potential income, I_E, between the consumption of leisure, l, and what is best termed effort, $\mathcal{E}f$. Expanded income, I_E, is equal to the rental value of the household's labour and capital endowments minus direct taxation plus transfer payments from government. This stage should be thought of as a leisure-work trade-off. Leisure can be thought of as costing, P_L, the net wage rate or after-tax return to labour as consumption of leisure involves forgoing labour income.

The second stage involves allocation of actual income, I, between present consumption, X, and saving, S. Saving is used to finance the purchase, through the investment sector (See Section 4.4) of additional capital which will be added to the household groups capital stock. Consumers are assumed to use their saving to buy a saving good[3], S, at a price, P_S. The price of saving can be interpreted as the purchase price of capital, as saving is invested immediately. The household groups are assumed to be myopic in that they assume that prices in the future will be identical to prices now. Due to the households' myopic outlook on life the income generated by the additional capital is thought of as financing future planned additional consumption.

In the third stage consumers allocate current consumption income, more properly termed expenditure, I_X, between the consumption goods. This involves a fixed proportion being spent on durables and the remaining (non-durable) consumption being decided by an Almost Ideal Demand (AID) system. Energy appears in the AID system and is, in a similar fashion to the other goods, a fixed co-efficient composite of its production sector components.

There is thus a restriction imposed that consumers are unable to substitute between different types of energy. They are assumed to consider energy generically, as a fixed mix of actual energy types.

Stage 1
Total Utility, U, is a CES function of effort, Ef, and leisure, l.

Stage 2
Effort Utility, Ef, is a CES function of goods expenditure, X, and future consumption, Fc.

Stage 3
Goods expenditure, X, is fixed co-efficent proportional division between durable onsumption, D and Non- durable consumption, X. Non-durable consumption, X1,...,Xn is determined by an AID system.

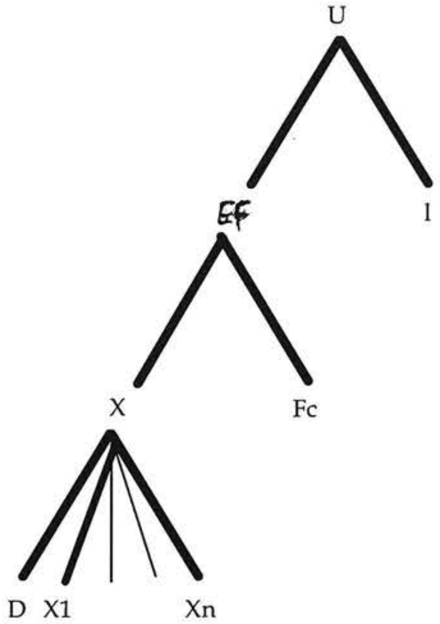


Diagram 4.2 - The structure of the household sector.

Each household supplies capital and labour and receives payment for these factor services. The inclusion of the numerous labour types is a useful complication. The labour types are shown in Table 4.1 and are denoted by an i subscript/superscript. The total labour endowment of each of the household groups is fixed sum and the, standard, relationship between labour supply, S_L, and leisure for each household is given by:

(4.2.1) $S_L = E_L - l$

where E_L is the labour endowment.

The relationship between gross wages received by households, w, and the net wage rate which is termed the price of leisure, P_l is given in Section 4.7.

The household group's expanded income, I_E, is given by the sum of total labour endowment, E_L times the net wage rate faced by the household, P_l, plus the total capital endowment, E_C times the net interest rate, P_K plus any transfer payments by the government, B. Payments to capital are subject to corporation tax, hence the need for a net interest rate. See Section 4.7. This relationship is given in Equation (4.2.2).

(4.2.2) $I_E = P_l E_L + P_K E_K + B$

In the first stage, the household groups choose between effort, Ef[4], and leisure, l. They face the budget constraint:

(4.2.3) $I_E = P_{Ef} Ef + P_l l$

where P_{Ef} is the price of effort. This is dealt with later in this section. Thus, using (4.2.3), the first stage of the consumers utility maximisation problem can be written:

(4.2.4) Max $U[Ef, l]$, subject to $I_E = P_{Ef} Ef + P_l l$

where I_E is given by equation (4.2.2). The consumers constant elasticity of substitution (CES) overall utility function, U, is given by:

(4.2.5) $$U = \left[\alpha^{\frac{1}{\sigma_2}} Ef^{\frac{\sigma_2 - 1}{\sigma_2}} + (1-\alpha)^{\frac{1}{\sigma_2}} l^{\frac{\sigma_2 - 1}{\sigma_2}} \right]^{\frac{\sigma_2}{\sigma_2 - 1}}$$

where α is a weighting parameter and σ_2 is the elasticity of substitution between Ef and l. Undertaking the constrained maximisation outlined in (4.2.4) yields the demand for effort, Ef, to be:

(4.2.6) $$Ef = \frac{\alpha I_E}{P_{Ef}^{\sigma_2} \theta_2}$$

and leisure, l to be:

(4.2.7) $$l = \frac{(1-\alpha) I_E}{P_l^{\sigma_2} \theta_2}$$, where

(4.2.8) $$\theta_2 = \alpha (P_{Ef})^{1-\sigma_2} + (1-\alpha)(P_l)^{1-\sigma_2}$$

The price of effort, P_{Ef} is discussed below. The supply of labour, S_L, is calculated using (4.2.7):

(4.2.9) $S_L = E_L - l = E_L - \frac{(1-\alpha)I_E}{P_l^{\sigma_2}\theta_2}$

This can be somewhat simplified to:

(4.2.10) $$S_L = E_L(1 - \frac{(1-\alpha)P_l^{1-\sigma_2}}{\theta_2}) - \frac{(1-\alpha)}{P_l^{\sigma_2}\theta_2}(P_K E_K + B)$$

Although examination of (4.2.10) does not shed light on the effect of changes in the net wage on labour supply (and hence the effect of changes in direct taxation) due to the complex functional form, it can be seen from the second expression on the right hand side that an increase in transfer payments, B, or the price of capital, P_K, will tend to reduce labour supply.

In the second stage, each household group maximises its sub-utility of effort by choosing between consumption, X, and Saving, S. They perform the following optimisation:

(4.2.11) $$\text{Max. } Ef = \left[(1-\beta)^{\frac{1}{\sigma_1}} X^{\frac{\sigma_1 - 1}{\sigma_1}} + \beta^{\frac{1}{\sigma_1}} S^{\frac{\sigma_1 - 1}{\sigma_1}}\right]^{\frac{\sigma_1}{\sigma_1 - 1}}$$ subject to:

(4.2.12) $$I = P_X X + P_S S$$

where β is a weighting parameter and σ_1 is, as before, the elasticity of substitution between composite consumption, X, and saving, S. Actual Income, I, is given by:

(4.2.13) $$I = S_L P_l + E_K P_K + B$$

This is basically equivalent to equation (4.2.2) with the endowment of labour replaced by the actual supply of labour in accordance with the household leisure-work trade-off. This constrained maximisation gives rise to the demand for composite present consumption, X and saving, S:

(4.2.14) $$X = \frac{(1-\beta)I}{P_X^{\sigma_1}\theta_1}$$

(4.2.15) $$S = \frac{\beta I}{P_S^{\sigma_1} \theta_1}, \quad \text{where}$$

(4.2.16) $$\theta_1 = (1-\beta) P_X^{(1-\sigma_1)} + \beta P_S^{(1-\sigma_1)}$$

The household purchases S worth of saving (investment) goods and thus spends $P_S S$ on saving This leaves the income available for goods consumption expenditure, I_X as:

(4.2.17) $$I_x = I - P_s S$$

In the third and final stage consumers choose the consumption components of X. Expenditure is first divided between durable and non-durable goods by a fixed co-efficent, Ω, which represents the proportion of I_X spent on durable goods. The remaining income, to be spent on non-durables, is given by I_{ND}, where:

(4.2.18) $$I_D = I_x - P_d \Omega$$

This income is spent on non-durables in line with an Almost Ideal Demand System . The budget shares, b, of each of the 7 non-durable goods are given by:

(4.2.19) $$b_i = \phi_i + \sum_j \varphi_{ij} \log P_j + \gamma_i \log\left(\frac{I_{ND}}{P_{ND}}\right) \text{ where}$$

(4.2.20) $$\log P_{ND} = \phi_0 + \sum_k \phi_k \log p_k + \frac{1}{2}\sum_k \sum_l \varphi_{kl} \log p_k \log p_l \quad \text{and}$$

P_i represents the price of consumption good i and ϕ,φ and γ are parameters. The ϕ parameters vary between households and this issue is taken up in Chapter 6. It will be noted that the Price Index, P_{ND}, defined by the AID system can be used in conjunction with the price of durable goods, P_D, to calculate the overall price index of goods expenditure, P_X. This is simply given by:

(4.2.21) $$P_X = \Omega P_D + (1-\Omega) P_{ND}$$

An important property of the CES utility functions is that the indirect utility functions can be easily derived. This allows calculation of the price of effort, P_{Ef}. This composite price for effort, P_{Ef}, is derived as follows. The effort sub-utility function, Ef, is composed of X and S. Substituting the demand functions for X and S, Equations (4.2.14) and (4.2.15) into Equation (4.2.11) gives:

$$(4.2.22) \qquad Ef = \left[(1-\beta)^{\frac{1}{\sigma_1}} \left[\frac{(1-\beta)I}{P_X{}^{\sigma_1}\theta_1} \right]^{\frac{\sigma_1-1}{\sigma_1}} + \beta^{\frac{1}{\sigma_1}} \left[\frac{\beta I}{P_S^{\sigma_1}\theta_1} \right]^{\frac{\sigma_1-1}{\sigma_1}} \right]^{\frac{\sigma_1}{\sigma_1-1}}$$

which can be written as:

$$(4.2.23) \qquad Ef = I\left[(1-\beta)^{\frac{1}{\sigma_1}} \left[\frac{(1-\beta)}{P_X{}^{\sigma_1}\theta_1} \right]^{\frac{\sigma_1-1}{\sigma_1}} + \beta^{\frac{1}{\sigma_1}} \left[\frac{\beta}{P_S^{\sigma_1}\theta_1} \right]^{\frac{\sigma_1-1}{\sigma_1}} \right]^{\frac{\sigma_1}{\sigma_1-1}}$$

and then can be simplified to:

$$(4.2.24) \qquad Ef = I\left[(1-\beta) \left[\frac{1}{P_X{}^{\sigma_1}\theta_1} \right]^{\frac{\sigma_1-1}{\sigma_1}} + \beta \left[\frac{1}{P_S^{\sigma_1}\theta_1} \right]^{\frac{\sigma_1-1}{\sigma_1}} \right]^{\frac{\sigma_1}{\sigma_1-1}}$$

Recapping on Equations (4.2.2) and (4.2.13) and rearranging each we have:

$$(4.2.25) \qquad I_E - P_l l = P_{Ef} H \text{ and } I = I_E - P_l l$$

Thus:

$$(4.2.26) \qquad I = P_{Ef} Ef$$

Using equations (4.2.24) and (4.2.26) we have:

(4.2.27) $$P_{Ef} = \left[(1-\beta)\left[\frac{1}{P_X^{\sigma_1}\theta_1}\right]^{\frac{\sigma_1-1}{\sigma_1}} + \beta\left[\frac{1}{P_S^{\sigma_1}\theta_1}\right]^{\frac{\sigma_1-1}{\sigma_1}} \right]^{\frac{\sigma_1}{1-\sigma_1}}$$

Taking out terms in θ_1, simplifying and substituting in for θ_1 from (4.2.13) we have:

(4.2.28) $$P_{Ef} = \left((1-\beta)P_X^{(1-\sigma_1)} + \beta P_S^{(1-\sigma_1)}\right)\left[(1-\beta)P_X^{(1-\sigma_1)} + \beta P_S^{(1-\sigma_1)}\right]^{\frac{\sigma_1}{1-\sigma_1}}$$

A final simplification gives:

(4.2.29) $$P_{Ef} = \left((1-\beta)P_X^{(1-\sigma_1)} + \beta P_S^{(1-\sigma_1)}\right)^{\frac{1}{1-\sigma_1}}$$

An identical procedure is used to derive the composite price of total utility, U. This gives the price of utility, P_U as:

(4.2.30) $$P_U = \left(\alpha P_{Ef}^{(1-\sigma_2)} + (1-\alpha)P_l^{(1-\sigma_2)}\right)^{\frac{1}{1-\sigma_2}}$$

Thus all variables in the consumption sector are defined. All that remains is to sum labour supply and goods demand over all the households. Household subscripts are now imposed. The total labour supplied is given by:

(4.2.31) $$S_L = \sum_h S_L^h$$

The total supply of capital is simply the sum of the endowments of the individual households:

(4.2.32) $$K_S = \sum_h E^h{}_K$$

It will be noted that the supply of capital is fixed, it is not dependant on the any variables. The final demands for each of the consumption goods are given by:

$$D^{D} = \sum_{h} \frac{\Omega^{h} I_{X}^{h}}{P_{D}} \tag{4.2.33}$$

for durables and by:

$$D^{ND}{}_{i} = \sum_{h} \frac{(1-\Omega^{h}) I_{X}^{h} w_{i}^{h}}{P_{i}^{ND}} \tag{4.2.34}$$

where D^{D} represents the total demand for durables and $D^{ND}{}_{i}$ represents the total demand for non-durable good, i. It is appropriate at this point to specify the relationship between the output of the production sector and the consumption goods in the model. Each consumption good is a fixed co-efficient composite of the output of the production sectors. Using non-durable goods as an illustration, Equation (4.2.35) shows the demand for the output of production sector j, D_j^{i}, given the demand for non-durable good i, only.

$$D_{j}^{i} = pc_{ij} D^{ND}{}_{i} \tag{4.2.35}$$

In Equation (4.2.36) pc_{ij} represents the amount of production good j, that is used in consumption (non-durable) good i. Thus the total consumption demand for production good j is given by Equation (4.2.37).

$$D_{j} = \sum_{i} pc_{ij} D^{ND}{}_{i} + pc_{Dj} D^{D} \tag{4.2.36}$$

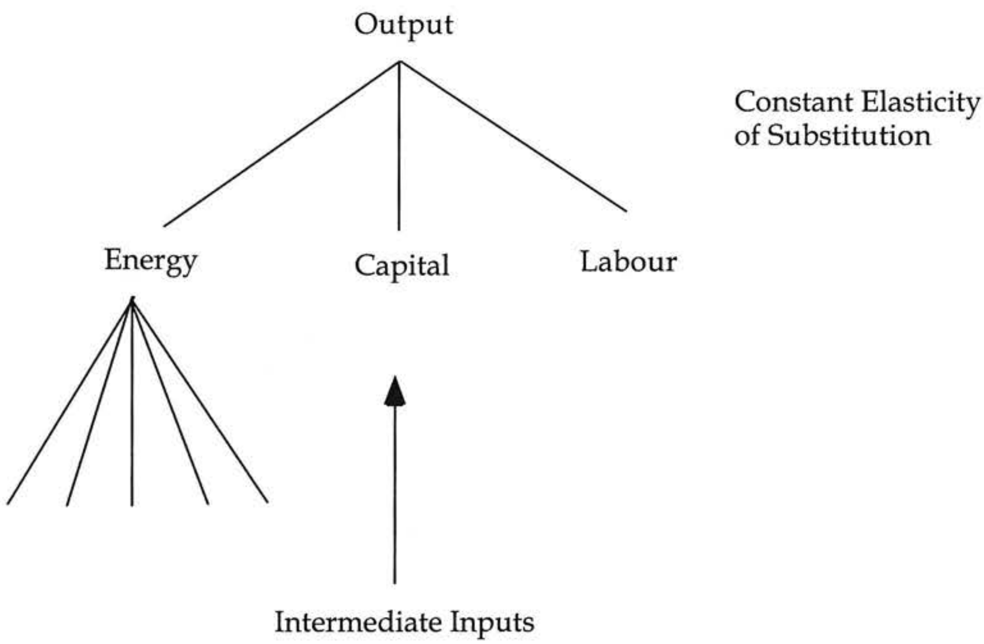
where pc_{Dj} represents the amount of production good j that is used in durable consumption goods. Finally, using Equation (4.2.36) and (4.2.37) the relationship between the consumer prices of the production sector, P_j^{C} and the consumer prices P_i^{ND} and P^{D} can be laid out.

$$\begin{aligned} P_{i}^{ND} &= \sum_{j} pc_{ij} P_{j}^{C} \\ P^{D} &= \sum_{j} pc_{Dj} P_{j}^{C} \end{aligned} \tag{4.2.37}$$

The relationship between producer prices and the consumer prices of the production sector can be found in Section 4.7.

4.3 The Production Sector

The production sector is represented by 17 perfectly competitive firms each producing a single, homogenous good. Each firm, which represents a sector, makes normal profits at all times and operates under constant returns to scale. A single sector is illustrated by the following diagram.



Each firm is assumed to minimise its costs per unit of output. Intermediate inputs are modelled as a fixed amount of the output (including own) of the other production sectors, excluding energy sectors, per unit output. This is referred to as a per-unit make matrix. As intermediate inputs are fixed per unit output they do not appear in the firms cost minimisation problem. Sector i's intermediate use of the output of sector j represented by II_{ij}, is given by:

(4.3.1) $II_{ii} = Q_i m_{ij}$

where m_{ij} is the amount of good j, sector i needs to produce one unit of output and Q_i is the output of sector i. Each firm also uses labour, L, Capital, K, and composite Energy, E. Composite Energy is a fixed co-eficient multiple of the energy types. The energy composites are shown in Table 4.3.

Table 4.3 - Energy Composites

Coal Extraction
Oil and Gas Extraction
Coke, Oil Production
Electricity
Gas

Thus, the amount of each energy type is given by:

(4.3.2) $E_{ik} = e_{ik}E_i \text{ where } \sum_k e_{ik} = 1$

The make matrix and the composite Energy make-up vary across sectors, as designated by the i subscripts. Capital, K, and Labour, L, are modelled however, as identical goods across sectors and are owned by households. Thus, the price of capital, P_K, and the price of labour, P_L, are constant across sectors. The price of energy, P_E, is not and is given by Equation (4.3.3).

(4.3.3) $P_E = \sum_j P_E{}^j e_j$

In equation (4.3.3) sector subscripts have been dropped. This convention will be used throughout the remainder of the section. Each sector's output is modelled by a constant elasticity of substitution production function between labour, capital and composite energy as follows:

(4.3.4) $Q = C\left(a_L L^d + a_K K^d + a_E E^d\right)^{\frac{1}{d}}$

where C is a shift parameter, δ is the elasticity of substitution between inputs and a_L,a_K and a_E are share parameters and:

(4.3.5) $\sum_{k=L.K.E} a_k = 1$

As each sector minimises its cost per unit output under constant returns to scale it is convenient to work in terms of labour, capital and energy per unit output denoted by lower case l, k and e. Thus each sectors cost minimisation problem is expressed as:

(4.3.6) $$\min_{l,k,e} P_L l + P_K k + P_E e$$
$$\text{s.t. } C\left(a_L l^d + a_K k^d + a_E e^d\right)^{\frac{1}{d}} = 1$$

Solution of this cost minimisation problem gives the per-unit output demand for labour, capital and energy as follows:

(4.3.7)
$$l = \frac{1}{C}\left(\Delta^{\frac{-1}{d}}\left[\frac{a_L}{P_L}\right]^{\frac{1}{(1-d)}}\right)$$
$$k = \frac{1}{C}\left(\Delta^{\frac{-1}{d}}\left[\frac{a_K}{P_K}\right]^{\frac{1}{(1-d)}}\right)$$
$$e = \frac{1}{C}\left(\Delta^{\frac{-1}{d}}\left[\frac{a_E}{P_E}\right]^{\frac{1}{(1-d)}}\right)$$

where :

(4.3.8) $$\Delta = \left(a_L{}^{\frac{1}{1-d}} P_L{}^{\frac{d}{d-1}}\right) + \left(a_K{}^{\frac{1}{1-d}} P_K{}^{\frac{d}{d-1}}\right) + \left(a_E{}^{\frac{1}{1-d}} P_E{}^{\frac{d}{d-1}}\right)$$

The profit per unit output of each firm is given by:

(4.3.9) $$\Pi = P^r + S - P_L l - P_K k - P_E e - P_M - V$$

where P^r is the amount the sector receives per unit, S is subsidy per unit, P_M is materials cost and V is a production tax[5] per unit. Materials cost, P_M, is given by:

(4.3.10) $$P_M = \sum_k m_k P_k^p$$

where P^p is the price production sectors must pay for their output. The relationship between P^r and P^p is detailed in Section 4.7. The production tax is a fixed percentage of the price each sector receives for its output. This is given by the Equation (4.3.11) and is dealt with in more detail in Section 4.7:

$$(4.3.11) \qquad V = t_V P^r$$

The total output of each sector adjusts so that total demand for the sector is satisfied. The constant returns to scale assumption means that as output changes, factor demands remain in the same proportion. In equilibrium the price received for each sector's output is adjusted so that profit per unit is equal to zero.

The total demand for each of the non-energy sector output is given by:

$$(4.3.12) \qquad Q_i = TD_i = C_i + I_i + G_i + X_i - M_i + \sum_j II_{ji}$$

where C_i is consumption demand, I_i is Investment Demand, G_i is government demand, X_i is export demand and M_i is import demand for the output of sector i. Investment, Government, Export and Import demand are specified in the relevant Sections. Consumption demand for the output of each sector is calculated from demand for the consumption goods by a transition matrix of the form:

$$(4.3.13) \qquad C_i = \sum_j D_{ND}{}^j pc^{ND}{}_{ij} + D_D pc_i^D$$

where pc^{ND}_{ij} is the proportion of non-durable consumption good j that is produced by sector i and pc^D_i is the proportion of durable consumption goods produced by sector i. The final term in Equation (4.3.12) is simply the total intermediate demand for the output of sector i. The Energy sectors are treated slightly differently in that the output of each energy sector is given by:

$$(4.3.14) \qquad Q_i = TD_i = C_i + I_i + G_i + X_i - M_i + \sum_j E_{ji}$$

The final term in Equation (4.3.14) is the total demand for energy type i as an input. Each firms total labour, L, capital, K, and energy demand is given by Equation (4.3.15):

$$L_i = Q_i l_i$$
(4.3.15) $$K_i = Q_i k_i$$
$$E_i = Q_i e_i$$

The demand for the individual of energy are given by Equation (4.3.16):

(4.3.16) $$E_i^j = E_i e_{ij}$$

The total demand for labour is given by:

(4.3.17) $$L_D = \sum_i L_i$$

It should be noted that the total demand for each energy type, as an input, is covered in Equation (4.3.14). Finally, the total demand for capital is given by:

(4.3.18) $$K_D = \sum_i K_D^i$$

This completes the exposition of the production sector.

4.4 The Government Sector

Although in reality the government sector deals with government expenditure and taxation, for the purpose of this analysis the two are treated separately. Thus, this section simply details the composition and cost of public expenditure, the G_i, term in Equation (4.3.12) and (4.3.14) and transfer payments between the government and the private sector in the form of benefits to households and subsidies to firms. The linkage between government expenditure and taxation is detailed in Section 4.7.

The treatment of government expenditure is relatively simplistic in that it is assumed to be constant. However, it should be noted that it is quantities purchased by the government that remain constant as opposed to expenditure . As prices change, the value, in monetary terms, of government expenditure will change but the physical goods and services will not. It is important to remember this distinction between constant expenditure and constant purchases.

The demand by the government for the output of each of the production sectors is constant and equal to G_i. Thus, the monetary value of public expenditure is given by:

$$(4.4.1)\quad PE = \sum_i p_i G_i$$

Public expenditure should be thought of, in the terms of this model, as a necessary prerequisite for the economy to function. The reason for this is that public expenditure does not appear explicitly or implicitly in either the utility functions of the household sector nor the production functions of the production sector. This may seem restrictive, but given that it is held constant, in quantity terms, it is satisfactory.

The other actions of the government sector, excluding taxation, are the payment of benefits to households and subsidies to firms. Subsidies to firms are approximated as a monetary value per unit produced. They appear in the firms profit function (Equation 4.3.12) and thus have a direct effect on the price of output (remembering that output price adjusts automatically so normal profit, only, is made). An increase in the subsidy to any sector will have its effect on the economy through its effect on the output price of that sector and through the increased burden on the public finances.

Benefits to households, B, are simply a fixed amount given to each household and are assumed to represent the wide range of benefits available in reality. Again, it should be noted that this formulation is by no means realistic but at the same time that the inclusion of transfer payments in a CGE model, in any form, is unusual. The increased complexity generated by attempting to formulate a mathematical representation of the benefit system was deemed to be inappropriate. Indeed, given that levels of benefit vary with household composition, in the sense of number and type of individuals rather than income, and households in this model are differentiated solely by income, the construction of such a mathematical approximation may well be inappropriate.

Total government expenditure is given by the sum of all benefits, subsidies and public expenditure as shown by Equation (4.4.2).

$$(4.4.2)\ GE = PE + \sum_h B_h + \sum_i S_i Q_i$$

The interaction of public expenditure and taxes and the government sectors budget position is dealt with in Section 4.7.

4.5 The Investment Sector

As detailed in section 4.2, each household group saves part of its income and these savings are used to finance new capital stock which will be available to the household in future periods. As the model is static, this future increase in the capital stock does not impact directly within the model. Rather, saving and thus investment represent primarily a demand for the output of those sectors of the economy that produce capital goods.

The capital goods, which in use, from Section 4.3, are assumed to be identical across all firms, are a constant fixed proportion mix of the output of the production sectors. To provide one unit of capital goods requires a certain, fixed, amount of the output of each of the production sectors. This is represented in Equation (4.5.1)

$$(4.5.1)\ I = \sum_i IM_i$$

where IM_i is the amount of the output of sector i required to produce one unit of capital goods. Thus the cost of capital, or alternatively the price of saving, is given by:

$$(4.5.2)\ P_s = \sum_i p_i IM_i$$

The total amount of capital stock formation is given by:

$$(4.5.3)\ NK = \frac{S}{P_s}$$

where NK is the total addition to the capital stock. This can be disaggregated by household to give:

$$NK_h = \frac{S_h}{P_s} \quad (4.5.4)$$

Finally, the demand from the investment sector for the output of the production sectors is given by:

$$I_i = IM_i \sum_h NK_h \quad (4.5.5)$$

4.6 International Trade

The economy is modelled as a small open economy with trade in all sectors. Due to the empirical difficulty in obtaining reliable estimates of the import and export price elasticity of demand for all sectors, a simplistic approach is taken to modelling trade. Exports and imports are taken as a composite good, X and M respectively.

For simplicity the exchange rate is defined in terms of a single foreign currency. This exchange rate is defined in Equation (4.6.1).

$$ER = \frac{d}{f} \quad (4.6.1)$$

The Exchange rate, ER, is defined as the amount of domestic currency, d, per unit of foreign currency, f. An example would be an ER of 2 representing there being 2 pounds Sterling (the domestic currency) to 1 Dollar (the foreign currency). It should be noted that this definition is purely a convention.

The composite price of exports, P^X, is given by :

$$P^X = \sum_i \psi_i P_i^P \quad (4.6.2)$$

where ψ_i is the share of sector i's output in the Export composite. The demand for exports, X, is given by the following expression.

$$X_i = A\left(P^X\right)^{\lambda} = A\left(P^X ER\right)^{\lambda} \quad \text{where } \lambda < 0, A > 0 \quad (4.6.3)$$

where A is a shift parameter and λ Given Equation (4.6.3) and the associated sign constraints, it is easy to see that the demand for Exports is an inverse function of their price, P^W. It should be noted that an increase in either the domestic price or the exchange rate, as it is defined, will reduce the demand for exports.

The supply of imports is:

$$(4.6.4)\quad M_i = B\left(P^X ER\right)^{\mu} \quad \textit{where } \mu < 0, A > 0$$

Given Equation (4.6.4) and its sign constraints, it can be seen that an increase in the domestic price or the exchange rate, as defined, will increase the supply of imports. Thus, from Equation (4.6.3) and (4.6.4), *ceteris paribus*, an increase in the domestic price will reduce the amount of exports and increase the amount of imports. This will affect the current account balance, CA as defined by Equation (4.6.5).

$$(4.6.5)\quad CA = \sum_i P_i^W X_i - \sum_i P_i^D M_i$$

It is assumed that in equilibrium the exchange rate adjusts so that there is a zero balance[6] on the balance of payments.

4.7 Taxation

The treatment of taxation in the model is complex and is intended to be as realistic a representation of the actual tax structure of the economy as possible. In looking at the structure of taxation it is useful to separate the production and consumption sectors. Section 4.7.1 examines the taxation of the household sector, Section 4.7.2 looks at production sector taxes and Section 4.7.3 ties these together by examining government revenue in total and the government's budget constraint.

4.7.1 *Taxation of the household sector*

Households face both direct taxes on their income, arising from their supply of factor inputs to the production process and indirect taxes on their expenditure.

Direct taxes, in the sense of income tax must be modelled in a simplified way. It would be desirable to realistically represent the actual structure of income tax in the real economy but this is not possible. In reality, income tax is charged at various rates, above a basic threshold, or income tax allowance, level of income. As income levels rise, marginal tax rates rise, through a series of bands. This is represented algebraically in Equation 4.7.1.

$$(4.7.1)\quad \begin{array}{lll} I < a \Rightarrow & t = 0 \Rightarrow & TR = 0 \\ a < I < b \Rightarrow & t = t_1 \Rightarrow & TR = t_1(I - a) \\ b < I & t = t_2 \Rightarrow & TR = (b - a)t_1 + (I - b)t_2 \end{array}$$

Equation (4.7.1) shows an income tax structure comprising a tax allowance, a, and two marginal tax rates, t_1 and t_2. Any income, I, above the allowance but below the threshold level for the higher rate, b, is subject to a marginal tax rate of t_1. Income above b is subject to a marginal tax rate of t_2. Total income tax paid is given by TR. This represents the UK income tax system pre 1994. Unfortunately, the tax structure represented by Equation (4.7.1) is a discontinuous function. As such, it is not suitable for incorporation into a general equilibrium model. The presence of a discontinuous function, such as Equation (4.7.1), in the structure of a general equilibrium model may result in an unstable solution, several solutions or no solution at all. Thus, a simplified structure is required. More specifically, the income tax function, in keeping with all functions in the model, needs to be smooth and continuous. With this in mind, the income tax structure is modelled by a single equation as shown by Equation (4.7.2).

$$(4.7.2)\quad t = t_m \Rightarrow TR = IT_m$$

In Equation (4.7.2) T_m represents the marginal tax rate faced and will differ between households. It would be possible to include a term that represented a tax allowance by the inclusion of a negative constant on the RHS of Equation (4.7.2). Unfortunately, in reality, income tax allowances vary with the composition of the household that faces them in terms of single or married individuals, children etc. In the context of the model however, households are differentiated only by income and thus the calculation of an implied tax allowance is difficult and given data constraints, overly complicated.

This raises an issue of particular importance in the context of the double dividend hypothesis. The fact that an increase in the income tax allowance, a, following an increase in environmental taxation is equivalent to the lump-sum return of revenue detailed in Section 1 would seem to be a major problem when the purpose of the analysis is to investigate the alternative. There would thus seem to be no grounds for a comparison. However, this lump-sum return of revenue can be simulated in the model by a rise in the level of benefits paid. As such, the omission of an approximation to tax allowances would seem acceptable given the resultant decrease in analytical complexity.

It must be admitted that the loss of separate tax bands is particularly regrettable in the context of an examination of distributional effects as such a tax structure may be altered to become more regressive or progressive very easily. In an equity context, there would thus be scope for the regressive effects of a change in the environmental tax structure to be offset by adjustment of the income tax structure in this manner. It is again possible to simulate such effects and this is dealt with in Section 6.

Thus each household will face a marginal tax rate of Tm. This does not immediately allow the exposition of the relationship between the gross return to labour (the gross wage) and capital (the gross rate of interest) and the net rates. This is due to the inclusion of taxes on the inputs to production, labour and capital, that are paid by the production sector. As defined in the model, the gross return to an input refers to the price paid by firms. This price must include labour taxes and corporation tax[7] respectively. Thus, the gross/net return to inputs relationship is detailed in Section 4.7.2.

The indirect taxation of the household sector is straightforward. Value Added Tax is paid in addition to any taxes paid by producers. Thus the consumer prices of the production sector are given by Equation 4.7.3.

$$(4.7.3)\quad P_j^C = T_V P_j^p \text{ if sector j is subject to VAT}$$

where T_V, is the VAT rate. Two issues should be noted from Equation (4.7.3). Firstly it is assumed that consumers pay all taxes that producers pay as VAT is added to the prices producer pay rather than the price producers receive (See Section 4.7.2). Secondly, some production sectors are zero-rated for VAT[8].

4.7.2 Taxation of the production sector

The taxation of the production sector falls into two categories: the taxation of inputs, labour and capital, and the taxation of output.

It is assumed that producers pay taxes on labour , e.g. employers' National Insurance contributions in the UK, payroll tax in the US. Using Equations (4.2.3), (4.3.3) and (4.7.2) the relationship between gross wages or the price of labour, P_L, paid by producers and the net wage received by households, P_l, can be specified.

$$(4.7.4)\quad p_l = w(1-T_m) = (1-T_m)\sum_k w_k e_k = \frac{(1-T_m)}{(1+T_L)} P_L$$

where T_L is the tax paid by producers on labour. It is assumed that this tax is constant across all labour types.

The cost of capital to firms, or the gross interest rate, P_K, is treated as the 'normal' profit of the production sector. As such it is subject to corporation tax. The relationship between the gross interest rate, P_K, and the net interest rate, P_{nK}, received by households is derived in a similar fashion to the above and is shown in Equation (4.7.5).

$$(4.7.5)\quad p_{nK} = \frac{(1-T_m)}{(1+T_K)} p_k$$

where T_K is the corporation tax rate.

The relationship between the price producers pay, P^p and the price producers receive, P^r, is given by Equation (4.7.6).

$$(4.7.6)\quad P^p = (1 + T_P)p$$

where T_P is the producer tax rate. Note that sector subscripts have been dropped. Thus the relationship between the price producers receive and consumers pay, P^C, is specified using Equation (4.7.3) and (4.7.6).

The total tax revenue, TR, raised is given by the sum of the tax raised by each of the five main taxes: Income tax (TR_m), Corporation tax (TR_K), Labour taxes (TR_L) and producer taxes (TR_p) and is shown in Equation (4.7.8).

$$TR = TR_{m\,v} + TR_K + TR_L + TR_P \quad where$$

$$(4.7.8)\quad \begin{aligned} TR_m &= T_m\left(L_S w + K_S P_{nK}\right) \\ TR_K &= T_K K_D P_K \\ TR_L &= T_L L_S P_L = T_L L_D P_L \\ TR_P &= \sum_{\substack{i= \\ non-energy}} p_i^r T_p^i\left(C_i + \sum_j II_{ji}\right) + \sum_{\substack{k= \\ energy}} p_k^r T_p^k\left(C_k + \sum_j E_{jk}\right) \end{aligned}$$

The governments budget surplus is given, using Equation (4.4.2) and (4.7.8), by Equation (4.7.9).

$$(4.7.9)\quad BS = GE - TR$$

The governments budget position in the baseline case is important in that it provides the benchmark by which revenue-neutral changes are imposed. This is dealt with in Chapter 5.

4.8 Solution Procedure

Although the setup of the model is somewhat complicated, the solution procedure is relatively simple. Appendix 4 details which of the components of the model are parameters, which are variables and which are the 'primary' variables that all other variables may be derived from. It is these primary variables that form the core of the solution procedure.

As shown by Equation (4.3.12) and (4.3.14) the output of each production sector adjusts automatically to equal the net demand. Quantities in the model are thus in terms of parameters and prices and hence are not solved for, directly. Simplistically, the solution procedure finds a set of the 'primary' price variables such that all markets clear.

These 'primary' prices that are solved for in the model are the prices received by each of the production sectors (P^r=18), the prices paid for labour and capital and the exchange rate (ER=1). The conditions that must be satisfied for an equilibrium are that all sectors make normal profit (18), the labour and capital markets clear (2) and the balance of payments is in equilibrium. These equilibrium conditions are given in Equation 4.8.1.

$$(4.8.1)\quad \begin{aligned} &\sum_j \Pi_j = 0 \\ &L_S = L_D \\ &K_s = K_D \\ &BP = 0 \end{aligned}$$

It is vital to note that the model is not a closed system due to that fact that the government sector does not 'clear'. There is no stipulation[9] that the government must balance its budget. As such, Walras' Law does not apply. Walras' Law states that in a system of n markets, if (n-1) are in equilibrium, then the nth must be in equilibrium also. This usually necessitates the use of a numuaire, or constant variable in a CGE model. As this model is not a closed system, this is not the case.

The solution to the model is the solution to the above system of 21 equations in 21 unknowns. Once a solution for these 21 variables is known, all other variables in the model are known.

4.9 Features of the model

As mentioned in the introduction, the model was developed with a specific purpose in mind - an analysis of the distributional implications of revenue-neutral tax reform, specifically with the imposition of environmental taxes. The specific environmental taxes that are imposed are taxes on energy. See Chapter 1.

There are thus two criteria that the model must be able to fulfil - it must be suitable for analysing distributional effects and it must also be suitable for analysing the effects of energy taxes. This section examines each of these issues in turn. The features that ease the analysis of distributional effects are considered first, as to a large extent they are unique, to this model, in this context. A final section (4.9.3) examines the consequences of the fact that the competitive general equilibrium framework implies labour market clearing, or no involuntary unemployment.

4.9.1 Distributional Effects

The main feature that the analysis of distributional effects necessitates is the inclusion of the analysis of multiple households. This issue was touched upon briefly in Section 4.2 but will be elaborated on in this section.

The approach chosen to include more than the standard, single representative household must be scrutinised in some detail. As mentioned in Section 4.2 it is possible to use either a 'single to multiple' approach or the reverse, a 'multiple to single approach'. The 'single to multiple' approach constructs a model for the entire economy, solves for the relevant variables - prices, quantities etc. and then disaggregates to separate households. This is analytically relatively simple as the equations that comprise the solution set of the model are reasonably straightforward. It is then simply a matter of applying disaggregation criteria to examine the effect of any imposed changes on a subset of the economy.

This approach was rejected for a number of reasons. Firstly, as was demonstrated in Chapter 3, with the inclusion of an average household for initial expositional simplicity, when dealing with the revenue-neutral tax changes in the context of the double dividend hypothesis, a single representative household approach can give misleading results. Certain, small, sectors of the economy may gain (or lose) so much that the overall effect is positive (or negative) even if the remaining, large portion of the economy loses (or gains). Thus average results can be very misleading if one cares about equity.

A major reason for the rejection of the single to multiple approach is simply that it wastes information. As an example, a specification of the individual separate demand structures of numerous households, particularly if these demand structures are complex in nature (such as the AID system[10]), will contain much more information and will give much more realistic results than representing the entire household sector by a single household. More specifically, it is almost certain that the demand characteristics of those households which have smaller market power will be 'lost' in such an amalgamation. This may be relatively unimportant for the economy as a whole, but will be very important when considering the effect on the particular household. This loss of information cannot be compensated for by then disaggregating the single household downwards. However, the issue of disaggregation is another major problem as it is not immediately clear how this disaggregation should be undertaken. More importantly, it will now be demonstrated how this disaggregation in itself can cause major problems.

To take the example of the AID system outlined in Section 4.2., the intercept terms in Equation (4.2.20) and (4.2.21) are allowed to vary between households. Expressing equation (4.2.20) in terms of demands rather than budget shares and adding household subscripts where appropriate we have:

(4.9.1) $D_i^h = \frac{I^h}{P_i}\left(\phi_i^h + \sum_j \varphi_{ij} \log P_j + \gamma_i \log\left(\frac{I^h}{P_{ND}{}^h}\right)\right)$ where

$$\log P_{ND}{}^{h} = \phi_0{}^{h} + \sum_k \phi_k \log p_k + \frac{1}{2}\sum_k \sum_l \varphi_{kl} \log p_k \log p_l$$

In the AID system, the parameters $\phi_i{}^h$ and $\phi_o{}^h$ must be calibrated to reflect the actual demands of each household. The other parameters, φ and γ, are estimated econometrically. For simplicity assume all prices are equal to unity. This gives:

$$(4.9.2)\quad D_i^h = I^h\left(\phi_i^h + \gamma_i\left(\log\ I^h - \phi_o{}^h\right)\right)$$

Assume, again for simplicity, that we have two households, denoted a and b. The total demand is given by:

(4.9.3)

$$D_i^h = \sum_{h=a,b} I^h\left(\phi_i{}^h + \gamma_i\left(\log\ I^h - \phi_o{}^h\right)\right) = I^a\left(\phi_i^a + \gamma_i\left(\log\ I^a - \phi_o{}^a\right)\right) + I^b\left(\phi_i{}^b + \gamma_i\left(\log\ I^b - \phi_o{}^b\right)\right)$$

This simple, two household demand structure could be represented by a single household, c. Household c could be modelled as having income equal to the average income of households a and b and the demand side economy would be represented by twice the demand of household c. This would represent the household sector as comprising numerous identical households and will be termed Scenario 1. Alternatively, household c could be modelled as having the joint income of household a and b. In this case the demand side of the economy would be represented by a single household and will be termed Scenario 2.

The total demand in the economy is now represented in the two scenarios by:

$$(4.9.4)\quad D_i^c = 2I^c\left(\phi_i^h + \gamma_i\left(\log\ I^c - \phi_o\right)\right) \qquad \text{Scenario 1, or}$$

$$D_i^h = I^c\left(\phi_i^c + \gamma_i\left(\log\ I^c - \phi_o\right)\right) \qquad \text{Scenario 2.}$$

Substituting in the relevant terms for the income of household c gives:

$$(4.9.5)\quad D_i^c = (I^a + I^b)\left(\phi_i^c + \gamma_i\left(\log\ \left(\frac{I^a + I^b}{2}\right) - \phi_o{}^c\right)\right) \qquad \text{Scenario 1, or}$$

$$D_i^c = (I^a + I^b)\left(\phi_i^c + \gamma_i\left(\log\,(I^a + I^b) - \phi_o{}^c\right)\right) \qquad \text{Scenario 2.}$$

In either case, the total demand represented by Equations (4.9.5) must be equal to the total demand represented by Equation (4.9.3) so giving:

(4.9.6)

$$I^a\left(\phi_i^a + \gamma_i\left(\log\ I^a - \phi_o{}^a\right)\right) + I^b\left(\phi_i^b + \gamma_i\left(\log\ I^b - \phi_o{}^b\right)\right) = (I^a + I^b)\left(\phi_i^c + \gamma_i\left(\log\left(\frac{I^a + I^b}{2}\right) - \phi_o{}^c\right)\right) \qquad \text{Scenario 1}$$

and

$$I^a\left(\phi_i^a + \gamma_i\left(\log\ I^a - \phi_o{}^a\right)\right) + I^b\left(\phi_i^b + \gamma_i\left(\log\ I^b - \phi_o{}^b\right)\right) = (I^a + I^b)\left(\phi_i^c + \gamma_i\left(\log\,(I^a + I^b) - \phi_o{}^c\right)\right) \qquad \text{Scenario 2}$$

The relevant part of Equations (4.9.6) must hold for the model to be correctly specified. However, due to the complex functional form of the demand system neither of the equations can be simplified further. Thus in either Scenario 1 or Scenario 2, there are additional restrictions imposed on the parameters that must be calibrated for households a and b. This results in it being unlikely that the demand system for the two households can be specified in terms of real world data.

The use of the 'multiple to single' approach, where households are specified individually and the total position calculated by summing them together does not suffer from either of these problems. It does have the disadvantage of making the entire model significantly more complicated.

The question of households are distinguished should be considered, briefly. The most obvious, and the chosen, way is by income. An equal number of households make up each income group. As will be seen in Chapter 5, there are ten household groups in the parameterised model, each representing a decile of income. It is of course possible to categorise households in many other ways, but when dealing with equity considerations this would seem to be the most sensible.

The choice of demand system has an effect on the ability of the model to analyse both distributional issues and the effects of energy taxes. The AID system, which is significantly more complex than the more common linear expenditure system, is used to specify the demand structure of the household sector for the primary reason that it incorporates cross price effects. This has important distributional implications but is vital in determining the effects of energy taxes, particularly in the context of revenue neutrality. See the discussion in section 1.2.1.

4.9.2 Energy Taxes

The key feature of the model in regard to its analysis of the effect of energy taxes is the inclusion of energy as a direct input to the production function of the private sector. There is thus substitutability between energy and labour and capital. This is vital if the analysis of the model is to be accurate. It is quite common for energy to be treated as any other (non-labour/capital) input to the production process, but this means that a model will fail to capture all effects of a rise in energy price. Possibly the worst case is where energy is included in the make matrix specified in Equation (4.3.1). If this route is followed, then the effect of rising energy prices will be transmitted simply by rising producer prices reducing demand for goods and services. Overall energy consumption will fall but only at the same rate as overall output.

Allowing substitution between energy and other inputs allows the production sector to act in a more realistic way. There will still be upward pressure on producer prices, but there will be scope for firms to use less energy per unit output. Thus, overall energy use may fall in two ways.

The inclusion of this ability does however raise the issue of adjustment time. The production sector in the model is assumed to minimise the cost per unit output and operate under constant returns to scale. This, coupled with the ability to substitute between energy and other inputs means that the model should not be thought of as considering short-run effects. The set-up is geared to analysing the effects of changes in the tax structure in the medium to long term. A single run of the model should be considered to represent a period of around five to ten years. This would seem a sensible time scale for changes of the magnitude that may take place.

Ideally, this whole issue could be clarified by the inclusion of some form of technological change, explicitly, within the model. One possible idea would be the use of a 'vintage' model of capital, where there would be an incentive from higher energy prices, to invest in machinery that is more energy efficient. At this stage, such an approach is too complex and more generally the issue of modelling technical change is fraught with empirical difficulty.

4.9.3 The consequences of labour market clearing.

As mentioned in section 4.1, the competitive general equilibrium nature of the model means that, by definition, the labour market clears and there is thus no possibility of involuntary unemployment being considered. It will be noted from the first chapter that those papers that do include involuntary unemployment tend to be more favourable to the notion of the double dividend than those that do not.

Bovenberg and van der Ploeg (1994) model involuntary unemployment in terms of a household wishing to supply more hours of labour than the production sector is demanding. They find that there is scope for a double dividend in terms of a reduction in pollution and a reduction in unemployment. However, as pointed out by Bonetti and Fitzroy (1999) this form of unemployment is, in effect, underemployment of existing workers. Bonetti and Fitzroy go on to point out that in practice, labour market rationing takes a rather different form in that full-time workers may prefer shorter hours and part-time workers may be content as they are. This issue has obvious distributional implications.

The model presented here does not distinguish between part and full-time work. In practice, lower income households tend to comprise more part-time workers than higher income households and data is available for the calibration, in such a manner, of the household sector. However, if this were the focus of the model it may be more sensible to differentiate households by labour type, rather than, as is done here, by income. The major problem is that data is not readily available for the proportion of each labour type employed by the various production sectors and as such the inclusion of such analysis is not practical in this model.

An obvious way of including involuntary unemployment in the this model is to keep wages constant and stop the labour market from clearing. This would, in effect, simplify the solution procedure as there would be one less variable to find a solution for. The effect of such a setup is not clear as the complexity of the model and it's 'black-box' nature makes prediction difficult. However, it is surmised that as capital is not fixed the effect may not be a strong as that found by Bonetti and Fitzroy. There is a major problem, however, in using such an approach. If the supply of labour outstripped the demand for labour from firms there is no difficulty - there is simply involuntary unemployment. The problem occurs if the demand for labour outstrips supply at the given wage rate and there is then an issue with how to allocate, or ration, the available labour to the production sector. One point is that any such rationing is likely to be unrealistic, as in reality different production sectors will face different constraints and data restrictions mean different labour types are not possible. The major issue is that in the course of finding a solution to the model it is likely that the solution procedure will switch between these two states. The fact that under this variation of the model, the actual level of labour used by firms is no longer a continuous function will simply mean that a solution to the model is not possible.

A way around this problem is for the model to consider endogenous wage determination through collective bargaining or efficiency wages. If tax reform were to increase employment then wage setters may sacrifice employment gains for higher wages. This issue is again pointed out in Bonetti and Fitzroy (1999). Such a system is not included due to the additional complexity involved. It is, unfortunately, extremely difficult to surmise what the result of such an addition would be (and it would obviously depend on the exact specification used). However, it may be expected that such an approach may enhance the possibilities for the existence of a double dividend as the more simplistic inclusion of involuntary unemployment does in the papers above.

In summary, although involuntary unemployment is not included in the model due to both the vastly increased complexity involved and data constraints, it is surmised that its omission may decrease the strength of the results in terms of finding a double dividend. As such, the results of the model should perhaps be viewed, with caution, as perhaps underestimating the extent of any double dividend.

4.10 Conclusion

This chapter has explained the theoretical setup of the model to be used in the next two chapters. Each component part of the economy has been explained separately in full detail and the linkages between each sector explained (Section 4.1 to 4.7). The solution procedure was explained in Section 4.8. Finally, the features of the model that were designed with its specific purpose in mind were outlined in Section 4.9.

Parameterisation and calibration is a complicated issue and is dealt with in Chapter 5 before results generated by the model are given in Chapter 6.

Notes:

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[1] With the exception of the government sector - there is no stipulation that the government must balance its budget. See Section 4.8.

[2]Cross trading of goods is a prominent real world phenomenon.

[3]This notation is used for simplicity in dealing with the household sector. In the model, all savings go to the purchase of investment goods (capital).

[4] Ballard et. al. use the notation, H, for the household's sub-utility of effort, termed here Ef. The notation is changed to avoid confusion. H is usually used for effort and may be interpreted in more simple models as hours worked. In this case, with a nested utility function, hours worked are just one component of the household's sub-utility of effort.

[5]The production tax, V, is equivalent to a composite of Value Added Tax and any excise duties. Due to informational constraints and the inclusion of energy as a specific factor of production, these two forms of tax - a percentage on the price of output over the cost of intermediate inputs and a fixed per unit amount - are modelled as a percentage of output price.

[6]It will be seen in the following section that the data used to calibrate the model is such that there is a trade deficit. The exchange rate is adjusted so that this deficit remains as was.

[7]As detailed in Section 4.3, the return to capital is thought of as the 'normal' profit of the production sector.

[8]Also, it is possible that VAT rates may vary across sectors although this is not explicitly stated.

[9]Until the issue of revenue-neutrality is considered - but in this case the revenue returning instrument is an additional variable.

[10]The reasons for using the AID system are dealt with later in this section.

Chapter 5 – Model data, Calibration and Sensitivity Analysis

This chapter deals with the data used in the model, the calibration of the model to this data and performs sensitivity analysis of the model to those parameters that were uncalibrated. Section 5.1 covers the data sources and manipulation required in detail, section 5.2 details the calibration procedures used and section 5.4 gives the results of a 'basic' run using the central parameters and section 5.5 performs the sensitivity analysis.

5.1 Model data

Data from two separate sources is used in the model. The primary data source is the Input-Output Tables for the UK 1990[1]. Although this is primarily production data, and it is detailed in section 5.1.1 below, it also contains aggregate measures of consumption, investment, exports and imports by production sector. It does not however contain disaggregated household data. This data was sourced for Economics Trends (1990) and is detailed in section 5.1.2. The use of two differing data sources and their use together is detailed in section 5.1.3. The overall, combined data for the economy is detailed in section 5.1.4.

5.1.1 Production, Investment, Government Spending and Trade

The source for data on production is the Input-Output Tables for the UK 1990[2]. This was the most recent data available of the form required[3]. The first part of the Tables consists of a Make Matrix (henceforth, MM), Domestic Use Matrix (henceforth, DUM) and Imports Use Matrix (henceforth, IUM). The MM provides a breakdown of domestic supply for each of the 123 commodities in terms of the producing industry - in other words, 'who makes what'. It shows, for each commodity, how much is produced by the industry for which it is the principal product and how much is produced by other industries as secondary products. The two Use Matrices show the input structure of industries in terms of either domestic (the DUM) or imported (the IUM) goods and services - in other words 'who uses what'.

Each column in a use matrix breaks down the inputs of an industry between intermediate and primary inputs. An industry pays wages to workers and indirect taxes to government. The excess of its output over the payment for intermediate inputs gives the gross operating surplus or the total return to capital in this model. Each row in the use matrix show how a particular commodity is distributed to other industries in terms of intermediate demand, or as a final demand to consumers expenditure, government expenditure (termed general government final consumption (GGFC)), investment (termed gross domestic fixed capital formation (GDFCF)), change in stocks and exports.

Thus, the use matrices contain sufficient information to calibrate the production sector of the model[4] as well as providing a large amount of data on the remainder of the economy. There are four major issues however:

- **Commodities versus Industries**

An important issue with the Input-Output tables is the distinction between industries and commodities (products). Industries are defined using the Standard Industry Classification, Revised 1980, (HMSO 1979), and commodities are defined as the principle output of each of these 123 industries. Each production unit is classified according to the main commodity they produce but it is, of course, possible that a particular production unit may produce more than one commodity. Because of this it is not possible to define the elements in the two classifications in such a way that there is a one to one correspondence between them.

This problem is easily overcome as the tables also include derived input-output tables in the form of a commodity by commodity[5] DUM and IUM. Use of this data means that the production sectors in the model reflect commodity output. Although, it is production sectors that are referred to, this distinction should be remembered.

- **Aggregation**

The Input-Output tables contain data on 123 separate industries which is much too large to be manageable. The data was aggregated into 18 production sectors. Table 5.1 (overleaf) shows the 18 sectors and the Standard Industry Classification groups that comprise them.

The sectors were chosen to represent sensible, broad product types. Although the division is somewhat arbitrary, it matches that used by Ballard et. al. (1985).

- **Energy Sectors**

There are five energy producing sectors included in the 123 sectors in the input-output tables. These sectors appear unaggregated in the model:

- Coal extraction etc.
- Extraction - Oil and Gas
- Coke production, oil production, nuclear fuel
- Electricity production
- Gas

The first two are primarily 'raw' energy materials production, the final two are 'final' energy products and the middle sector is somewhat of a mixture. It will be recalled from the previous chapter that energy appears as a input, along with labour and capital, in each firms production function. Thus, care must be taken to exclude the energy sectors as intermediate goods.

- **Values to Quantities**

The input-output tables are denoted in units of millions of pounds sterling at basic prices (excluding taxation). By assuming that all producer receives prices are initially set to unity (see Section 5.2.1), one unit of output in the model represents £1 million pounds of 1990 output in reality. This allows a simple interpretation of the model's results.

Table 5.1 - Aggregation of 123 Standard Industry Classification commodities to 18 Model Commodities.

Alcohol and Tobacco (a)	Alcoholic drink, Soft drinks, Tobacco
Clothing (c)	Clothing and furs, Footwear, Hosiery and other knitted goods, Leather and leather goods, Textile finishing, Woollen and worsted,
Durables (d)	Other machinery and mechanical equipment, Office machinery and computer equipment, Basic electrical equipment, Electrical equipment for industry, batteries, etc., Telecommunication etc. equipment, electronic capital goods, Domestic electric appliances[a], Electric lighting equipment, etc., Motor vehicles and parts, Shipbuilding and repairing, Aerospace equipment manufacturing and repairing, Other vehicles, Instrument engineering , Timber processing and wood products (not furniture), Wooden furniture, shop and office fittings,
Coal Extraction (e1)	
Oil and Gas Extraction (e2)	
Coke, Oil Production (e3)	SEE SECTION 5.1.1.3
Electricity (e4)	
Gas (e5)	
Food (f)	Agriculture and horticulture, Oils and fats, Slaughtering and meat processing, Milk and milk products, Fruit, vegetables and fish processing, Grain milling and starch, Bread, biscuits and flour confectionery, Sugar, Confectionery, Animal feeding stuffs, Miscellaneous foods
Government (g)	Public administration, Education, Research and development, Health services
Household Durables (hd)	Electronic consumer goods, records and tapes, Carpets and other textile floor coverings, Jewellery and coins, Ownership of dwellings
Other (o)	Water supply, Glass, Refractory and ceramic goods, Paints, dyes, pigments, printing ink, Specialised chemicals for industry and agriculture, Pharmaceutical products, Soap and toilet preparations, Electronic components and sub-assemblies, Household and other made-up textiles, Paper and board products, Rubber products, Processing of plastics, Sports goods and toys, Other goods
Construction Materials (m)	Cement, lime and plaster, Concrete, stone, asbestos and abrasive products, Metal goods, Insulated wires and cables, Construction
Services (s)	Printing and publishing, Hotels, catering, public houses, etc., Postal services, Telecommunications, Banking and finance, Insurance, Auxiliary financial services, Accountancy services, Computing services, Renting of movables, Sanitary services, Recreational and welfare services, Personal services, Domestic services
Business Services (bs)	Wholesale distribution, Distribution & repair of vehicles, filling stations & other goods, Retail distribution, Legal services, Other professional services, Advertising, Other business services
Transport (t)	Railways, Road and other inland transport, Sea transport , Air Transport , Transport services
Capital Goods (z)	Structural clay products, Chemical products, Metal doors, windows, etc., Industrial plant and steelwork, Agricultural machinery and tractors, Metal-working machine tools, Engineers small tools, Textile machinery, machinery for working other materials, Process machinery and contractors, Mining, construction and mechanical handling equipment, Mechanical power transmission equipment, Ordnance, small arms and ammunition

Raw Materials (zm)	Forestry, Fishing, Extraction of metalliferous ores and minerals, Iron and steel, and steel products, Aluminium and aluminium alloys, Other non-ferrous metals (including precious metals), Extraction of stone, clay, sand and gravel, Inorganic chemicals, Organic chemicals, Fertilisers, Synthetic resins and plastic materials, synthetic rubber, Man-made fibres, Metal castings, forgings, fastenings, springs, etc., Packaging products of metal, Cotton etc. spinning and weaving, Jute etc. yarns and fabrics, and miscellaneous textiles, Pulp, paper and board, Owning and dealing in real estate[b]

Notes:

a: Domestic electric appliances are included in durables, rather than Household durables as £771 mill is used as intermediate inputs, as opposed to £335mill for consumption.
b: Real estate can be considered land and as such a 'Raw material' of production

5.1.1.1 The DUM and IUM

Bearing in mind the four points raised above the DUM and IUM for the model were calculated (by summing the appropriate values from the Input Output Tables from the relevant disaggregated sectors) and can be found in Appendix 5a and 5b respectively. As an example, the highlighted square in the DUM indicates that the Alcohol and Tobacco sector uses 723.2 units of the food sector's output as an intermediate goods, a total of 4150.6 units of intermediate goods and produces 8592.9 units of it's own product. From the opposite perspective, the food sector sells 723.2 units of it's output to the Alcohol and Tobacco industry as a intermediate input.

5.1.1.2 The Intermediate Use Matrix per unit output matrix

The Intermediate Use Matrix, i.e. 'how much of each sectors output, each sector uses to produce one unit of its own output'. Is calculated by adding the values in the corresponding cells in the DUM to those in the IUM and dividing each of these values (the total intermediate - domestic and imported - inputs of each sectors output that each sector uses) by the output of the sector concerned (by column). The Intermediate Use matrix is given in Appendix 5c. By way of illustration, the durables sector uses 0.0424 units of Construction Materials per unit of its output (the shaded cell in the table). Note that there are no rows in the Intermediate Use Matrix for the energy sectors (e1, e2, e3 ,e4 e5) as Energy in a modelled as a factor of production rather than a fixed intermediate good.

5.1.1.3 Factors of production

Information on the use per unit output of the factors of production in the model - labour, capital and energy - is taken from the DUM and IUM, and are shown in Table 5.2. The return to capital, p_K, and wage costs of producers, p_L, are set, initially to unity. Thus the labour and capital inputs of each sector are given by the appropriate row in the DUM. Dividing by each sector's output gives the per unit labour and capital demand.

The energy inputs of each sector comprise a composite of output of the five energy producing sectors. The energy composite demand per unit is simply total energy demand divided by output, for each sector. The shares of each energy component, e_{ij}, are calculated as the fraction of each energy type that comprises the sectors energy input. This information is clearly available from the DUM and IUM.

Table 5.2 - Factor use per unit.

	Factor use per unit			Proportion of each energy type per unit energy input				
	L/Unit	K/Unit	**E/Unit**	bE1	bE2	bE3	bE4	bE5
a	**0.16**	0.16	**0.01**	0.06	0.00	0.32	0.38	0.25
c	**0.33**	0.06	**0.01**	0.07	0.00	0.09	0.56	0.29
d	**0.31**	0.05	**0.01**	0.02	0.00	0.35	0.47	0.17
e1	**0.46**	0.03	**0.05**	0.19	0.00	0.00	0.79	0.02
e2	**0.08**	0.41	**0.07**	0.00	1.00	0.00	0.00	0.00
e3	**0.06**	0.15	**0.66**	0.01	0.84	0.14	0.00	0.00
e4	**0.11**	0.09	**0.66**	0.22	0.00	0.07	0.71	0.00
e5	**0.21**	0.14	**0.57**	0.00	0.93	0.00	0.00	0.07
f	**0.24**	0.11	**0.02**	0.03	0.05	0.33	0.44	0.15
g	**0.92**	0.10	**0.00**	0.00	0.00	0.16	0.58	0.26
hd	**0.00**	0.53	**0.00**	0.00	0.00	0.27	0.55	0.18
o	**0.29**	0.10	**0.02**	0.03	0.03	0.31	0.43	0.20
cm	**0.20**	0.13	**0.01**	0.14	0.00	0.33	0.39	0.13
s	**0.36**	0.15	**0.01**	0.00	0.00	0.26	0.59	0.15
bs	**0.44**	0.09	**0.01**	0.00	0.00	0.26	0.53	0.21
t	**0.30**	0.12	**0.03**	0.01	0.00	0.67	0.22	0.10
z	**0.36**	0.09	**0.02**	0.02	0.00	0.34	0.44	0.19
zm	**0.23**	0.08	**0.05**	0.19	0.03	0.42	0.23	0.14

Examining the table, it is immediately noticeable that sector e2 (Oil and Gas extraction) primarily appears as an input, as one would expect, to sectors e3 and e5 - Oil and Coke production and gas production respectively.

5.1.1.4 Investment

The composite capital good I, which comprises Investment in the model, as given by equation (4.5.1), requires knowledge of IM_i, the amount of output of sector i required to produce one unit of capital goods. This is calculated from the DUM and IUM. Again, the two use matrices are summed together to give the total amount of each sector's output that comprises investment, and each value is divided by total investment to give the share of each sector's output in the investment composite. This is shown in Table 5.3 below.

Table 5.3 – Investment, Government Quantity purchased and producer tax rates.

	Investment composite share	Government – quantity purchased	Government – Producer tax rate
a	0	55.12639	0.069135
c	0	601.2469	0.034611
d	0.014673	765.9456	0.022812
e1	0	83.48779	-0.11709
e2	0	0	0.004483
e3	0	687.1051	0.100753
e4	0	896.569	0.121156
e5	0	525.3222	0.185328
f	0	1524.884	-0.03298
g	0	75710.99	0.138738
hd	0	0	0.004712
o	0.000157	5200.992	0.039851
cm	0.515484	5152.83	0.009107
s	0.005259	4204.636	0.083732
bs	0.069401	3861.003	0.113445
t	0.1233	6747.896	0.024714
z	0.268484	8255.359	0.028745
zm	0.003242	1611.091	0.065101

5.1.1.5 Government Expenditure and Taxes

Government expenditure in terms of quantity purchased of the output of each sector is simply taken from the DUM and IUM in a similar manner to above and is reported in Table 5.3. It is important to remember, from section 4.4, that although the quantity of government output remains constant, expenditure will not, as prices change.

Producer taxes rates are calculated from the DUM, using the Taxes-Subsidies, row by solving a system of equations of the form:

$$\begin{pmatrix} D_{1,1} & \cdots & D_{i,1} & \cdots & D_{18,1} \\ D_{1,j} & \cdots & D_{i,j} & \cdots & D_{18,j} \\ D_{1,1} & \cdots & D_{i,18} & \cdots & D_{18,18} \end{pmatrix} \begin{pmatrix} t_1 \\ \vdots \\ t_j \\ \vdots \\ t_{18} \end{pmatrix} = \begin{pmatrix} R_1 \\ \vdots \\ R_j \\ \vdots \\ R_{18} \end{pmatrix} \tag{5.1}$$

where $D_{i,j}$ is the element in the ith row and jth column of the DUM, t_j is the producer tax rate on good j, and R_j is the tax revenue from good j. This system of 18 equations in 18 unknowns, (the t_j's), may be solved for the producer tax rates in each sector. The results are again shown in Table 5.3.

5.1.1.6 Trade

As detailed in section 4.6, exports and imports are treated as composite goods, due to the difficulty in obtaining reliable estimates of trade elasticities, separately, for the 18 production sectors.

The level of exports and imports of each of the production sectors is determined from the appropriate column in the DUM (for exports) and the appropriate row in the DUM (for imports)[6]. By dividing each sectors contribution by the appropriate total the share of each production sector in the Export and Import composites is determined. This data is shown in Table 5.4.

Table 5.4 - Composition of Export and Import composites

	Share of sector in total				
Sector	Exports	Imports	Sector	Exports	Imports
a	0.0219	0.0162	g	0.0003	0.0112
c	0.0438	0.0763	hd	0.12	0.16
d	0.0072	0.0145	o	0.1182	0.1208
e1	0.0013	0.005	cm	0.0161	0.0189
e2	0.0448	0.0326	s	0.0403	0.0202
e3	0.0221	0.0206	bs	0.0301	0.0205
e4	0.0015	0.0015	t	0.1969	0.1843
e5	0	0	z	0.2616	0.1715
f	0.0823	0.1289	zm	0.1115	0.157

5.1.2 Consumption Side

Consumption data was taken from Economic Trends, 1990, and its Supplement. Data was available on the household demand for consumption goods and household income, for each decile of the income distribution. In both cases the data had to be matched to the production data taken from the input-output tables. This process is dealt with in section 5.1.3. Section 5.1.2.1 details the data available on expenditure and section 5.1.2.2, the data on income.

5.1.2.1 Expenditure data

Data was available on the weekly household expenditure on consumption, broken down by consumption good category, for each decile of household income. The expenditure data is for the categories used by Pashardes (1993) in estimating his AID system (see section 4.1, equation 4.2.20 and 3.3.1). The seven non-durable categories form the AID system and expenditure on durables makes up the remainder. As households in the model are differentiated this way this data was in an ideal form. The first stage was to split the data into durable and non durable goods. Then, for each household, it was trivial to calculate the budget share of each of the consumer goods for each household. This is shown in Table 5.5.

Table 5.5 - Breakdown of household expenditure

Household	Durable share	Non-durable Share	Share of each non-Durable good: Food	Alcohol	Fuel	Clothing	Transport	Other	Services
1	0.159	0.841	0.297	0.143	0.028	0.026	0.05	0.345	0.111
2	0.146	0.854	0.283	0.129	0.026	0.033	0.062	0.351	0.116
3	0.142	0.858	0.268	0.096	0.026	0.035	0.087	0.365	0.122
4	0.136	0.864	0.217	0.085	0.029	0.037	0.105	0.38	0.146
5	0.129	0.871	0.235	0.074	0.029	0.042	0.111	0.368	0.14
6	0.138	0.862	0.23	0.06	0.028	0.04	0.112	0.385	0.145
7	0.133	0.867	0.224	0.059	0.027	0.042	0.116	0.369	0.163
8	0.128	0.872	0.219	0.053	0.025	0.044	0.116	0.37	0.172
9	0.133	0.867	0.209	0.047	0.024	0.048	0.115	0.392	0.164
10	0.121	0.879	0.185	0.041	0.022	0.051	0.113	0.371	0.216

When used in conjunction with data on the breakdown of household income into savings and expenditure (see following section), Table 5.5 is sufficient to calibrate consumption demand.

5.1.2.2 Household income

Data was available on household income across the 10 households of the income distribution. This data was in terms of the weekly income of each decile, broken down by income source - in the terms of the model: Labour, Capital and Government transfers. From this data the share of total income accrued by each of the household types could be calculated, as could the share of each household's income by source. This is shown in Table 5.6.

The first column in table 5.6 can be interpreted as follows: the top 10% of households account for 28.2% of household income. As one would expect the share of income from transfers declines dramatically as one moves up through the household groups. It is, at first glance, perhaps surprising that the increase in the share of labour income is more dramatic that the increase in the share of capital income. This should be interpreted as the fact that the top 10% of households still include a large number actively supplying labour, rather than living off capital. It is interesting to note that the share of income for labour for this highest category does decline from the share in the previous category (Household 9). In the model, income from capital includes private pensions[7] etc. as well as other savings/investments. It is surmised that the bi-modality of the share of income due to capital at household 4 and 10 is due to the effect of pensions - a significant proportion on those in the 4^{th} household decile - slightly below average income - are pensioners who do not supply labour income.

Table 5.6 - Breakdown of total income by household and household income by category

Household	Share of total income	Breakdown of household income by category: Labour	Capital	Transfers
1	0.02	0.016	0.076	0.908
2	0.027	0.037	0.166	0.721
3	0.039	0.139	0.223	0.534
4	0.054	0.298	0.248	0.312
5	0.072	0.399	0.243	0.195
6	0.093	0.484	0.215	0.125
7	0.112	0.523	0.216	0.095
8	0.135	0.555	0.208	0.068
9	0.166	0.574	0.209	0.051
10	0.282	0.558	0.267	0.035

Data is also available on the amount of income taxation paid by each household decile. Given the absolute income levels of each decile, and excluding transfers from taxable income, the marginal tax rates faced by each household type may be calculated. This is shown in table 5.7.

Table 5.7 - Marginal tax rates by household.

Household	Marginal tax rate faced
1	0.0282
2	0.0404
3	0.1259
4	0.1617
5	0.1744
6	0.1832
7	0.2024
8	0.206
9	0.2137
10	0.2353

These marginal tax rates allow for: a) the assumption of no taxation on transfers and b) the existence of income tax allowances which are not modelled explicitly[8].

Section 5.1.3 now details how the production and household data, from two separate sources, were matched.

5.1.3 Matching of the production and household data

The household side data described above allowed consumption shares of the household consumption goods, household income and income tax rates to be determined. This data was now matched with the production side data. The first issue was that the consumption data for the AID system contained 7 consumption commodities (the addition of durables gives the total consumption picture) whilst the production data is for 18 sectors. The production sectors were allocated to the consumption commodities according to table 5.8.

Table 5.8 - Allocation of production sectors to consumption commodities

Consumption Commodity	Allocated production sectors
Food	Food (f)
Alcohol and Tobacco	Alcohol and Tobacco (a)
Clothing	Clothing (c)
Transport	Transport (t)
Other	Other (o), Government (g), Construction Materials (m), Raw Materials (zm)
Services	Services (s), Business Services (bs)
Durables	Durables (d), Household (Durables), Capital Goods (z)
Energy	Coal Extraction (e1), Oil and Gas Extraction (e2), Coke, Oil Production (e3), Electricity (e4), Gas (e5)

Thus, there is a one to one relationship between Food, Alcohol and Tobacco, Clothing and Transport. The remaining consumption commodities (Other, Services, Durables and Energy) are composites of the remaining production sectors. The Consumption columns in the DUM and IUM allow the form of this composition to be determined by dividing the sum of the DUM and IUM consumption values for each production sector in each consumption composite by the total of the sum of the DUM and IUM values for the production sectors allocated to that consumption composite. The results are shown in table 5.9.

As an illustration, the consumption commodity, Services, comprises 97.48% Services and 2.52% Business Services, in terms of the production sectors.

Finally, the initial consumption tax rates are those used in chapter 3 and shown in Table 3.3.

Table 5.9 – Production sector composition of the consumption commodities.

	Food	Alcohol	Clothing	Transport	Other	Services	Durables	Energy
a	-	1	-	-	-	-	-	-
c	-	-	1	-	-	-	-	-
d	-	-	-	-	-	-	0.089	-
e1	-	-	-	-	-	-	-	0.0239
e2	-	-	-	-	-	-	-	-
e3	-	-	-	-	-	-	-	0.2294
e4	-	-	-	-	-	-	-	0.4207
e5	-	-	-	-	-	-	-	0.3260
f	1	-	-	-	-	-	-	-
g	-	-	-	-	0.1036	-	-	-
hd	-	-	-	-	-	-	0.7721	-
o	-	-	-	-	0.1581	-	-	-
cm	-	-	-	-	-	-	0.1389	-
s	-	-	-	-	-	0.9748	-	-
bs	-	-	-	-	-	0.0252	-	-
t	-	-	-	1	-	-	-	-
z	-	-	-	-	0.7245	-	-	-
zm	-	-	-	-	0.0138	-	-	-

Turning to household income, the data on household share of total labour, capital and transfer income in table 5.5 allows the calculation of individual household income. This is done by using total payments to labour and capital from the DUM to calculate individual household labour and capital income using the breakdown of income data. Then transfer payments are determined (which are not given directly in the Input-Output tables but appear in a Sales by final demand component) using the share of transfer payments in each household income.

5.1.4 The whole economy data

The data constructed in sections 5.1.1 to 5.1.3 above translates relatively simplistically to a picture of the entire economy. Given the information in the DUM and IUM of total output of Production and Imports and the allocation to Consumption, Investment, Government Spending and Exports, it is a simple process to determine data for the economy as a whole. Due it's size, this 'snapshot' of the economy is given in Appendix 5d.

The inclusion of Stocks in the Input-Output data which are not modelled explicitly here means that this component is used as a adjustment variable to ensure matching of the output and expenditure of the economy.

Section 5.2 now details the procedures used to calibrate the model using this data.

5.2 Calibration

This section deals with the calibration of the model to the data outlined in section 5.1. Production is dealt with initially, in section 5.2.1, followed by investment, government expenditure and trade in section 5.2.2. The household side of the model is considered in section 5.2.3 and finally, section 5.2.4 summarises the non-calibrated parameters that are subjected to sensitivity analysis in section 5.3.

5.2.1 Production

This section makes constant reference to section 4.3 of the preceding chapter. The first stage of the calibration process is to ensure that, with unit producer receives prices, each sector is making normal profits. This is given by equation (4.3.9). Unfortunately, the data is such that (4.3.9) is not automatically such that zero normal profits exist[9]. The solution is to specify a level of 'capital utilisation' for each sector such that each sector makes zero profit. The 'capital utilisation' parameter takes the form of a percentage reduction in the per-unit capital required by each sector. This results in a imbalance between total capital use in the economy and total capital available from households. Thus the process of matching the household income (by type) data detailed above must be repeated for the revised production capital usage data.

By calculating the 'capital utilisation' parameter so that, given the data, equation (4.3.9) shows zero profits for all sectors the zero normal profit assumption is satisfied. The capital utilisation parameters, as may be seen from (4.3.9) are independent of any other parameters in the model and are shown in table 5.10.

Table 5.10 - Capital utilisation by sector and production function coefficients

Sector	Capital Utilisation parameter	a_L	a_K	a_E	C	d
a	0.92919	0.344	0.470	0.185	7.062	-0.175
c	0.692216	0.462	0.353	0.185	3.603	-1.118
d	0.615011	0.480	0.335	0.185	3.687	-1.115
e1	1.994441	0.432	0.324	0.244	2.824	-0.822
e2	0.968573	0.237	0.532	0.231	3.172	-0.703
e3	0.778531	0.210	0.355	0.436	2.138	-0.439
e4	0.783935	0.249	0.299	0.451	2.110	-0.420
e5	0.50544	0.298	0.296	0.406	2.529	-0.457
f	1.049644	0.378	0.426	0.196	5.426	-1.379
g	0.064428	0.654	0.205	0.141	1.174	-0.055
hd	0.969978	0.000	0.885	0.115	1.953	-0.046
o	0.72478	0.416	0.384	0.200	4.323	-1.406
cm	1.504534	0.353	0.490	0.157	5.274	-0.643
s	0.774027	0.415	0.417	0.168	3.686	-0.904
bs	0.469967	0.489	0.344	0.166	2.715	-0.704
t	0.861966	0.389	0.395	0.216	4.306	-1.271
z	1.114445	0.417	0.401	0.182	3.629	-0.992
zm	1.087854	0.370	0.379	0.251	5.518	-1.790

The second stage of the calibration process involves the calibration of the production function parameters. Each production sector's production function is given by (4.3.4). Examination of this function shows that the parameters C, a_l, a_k,a_E and d, the shift parameter, the share parameters and elasticity of substitution between inputs respectively, require calibration for each production sector. Given the constant returns to scale assumption, rephrasing (4.3.4) in terms of per-unit inputs (given by table 5.2), recalling that the share parameters sum to unity and including the three factor demand functions given by (4.2.7) gives 4 equations in four unknowns for each production sector. Thus, the use of CES production functions means that it is possible for all parameters in the production sector to be calibrated by the data. The calibrated production parameters are given in table 5.10.

In examining table 5.10 it can be seen that the elasticity of substitution between inputs is less than 1 in absolute terms for all but 5 of the sectors and is below 0.8 (in absolute terms) for half of the sectors. Thus, the substitutability between imports is, generally speaking, not high. This is consistent with the thought of the model being one that deals with the short to medium run.

5.2.2 Investment, Government Expenditure and Trade

The total level of investment is given by the level of saving and the investment demand for each of the sector's output is simply the share times the total level of investment. Thus, no additional calibration is required. Government consumption is fixed so again no calibration is required.

Trade consists of a composite export good and a composite import good. Export and Import demand are given in (4.6.2) and (4.6.3) respectively. Given the composite price of each the shift parameter must be calibrated to the uncalibrated (determined) elasticity parameter so as the initial demands are correct. This is a areas where sensitivity analysis is important. See section 5.3.1. However, in line with Ballard et. al. (1985), -1.4 and 0.4 are used as the central case for the export and import price elasticities respectively.

5.2.3 Consumption and the household

The calibration of the household sector is relatively complicated. Marginal tax rates are calculated for each household from the basic data. Given the income information detailed in section 4.1.3, the parameters remaining are the share and elasticity parameters in the two utility functions and the intercepts of the AID for each household.

Initially, the AID system is calibrated, using the calculated household income and savings data (to match the production data) detailed in section 5.1.3. Given each household's expenditure (income minus savings) and durable share, the expenditure of each household on the AID system can be determined, as well as durable demand. The only parameters that vary between households are the intercept terms in (4.2.20) and it is relatively straightforward to calculate the values required such that actual budget shares are equal to those in the data (detailed in table 5.5). This is invariant to changes in any other parameters and is reported in Appendix 5e.

The next stage of the procedure is to calibrate the household utility function so that, given the sub-utility demand functions, household income and savings (and thus expenditure) match the data. There are two unknown parameters in each utility function (see (4.2.7) and (4.2.12)) and two equations - the supply of labour (or conversely the demand for leisure given the previous calculation of household labour endowments), see (4.2.8), and the level of savings, see (4.2.16). Thus there are two equations in four unknowns. Hence, the choice to calibrate either the shift or the elasticity parameters. The obvious choice is the shift parameters and they are thus calibrated to given elasticity parameters.

This leaves the elasticity of substitution parameters - the elasticity of substitution between leisure and effort and the elasticity of substitution between consumption and savings - to be determined outside the model. Considering the elasticity of substitution between leisure and effort, it is possible to calculate a value for a given uncompensated wage elasticity of labour supply, UWELS, - a value for which many empirical estimates exist. The formulae is shown below:

$$\sigma=\left[\frac{1}{UWELS}+\frac{p_l E}{I}-\frac{p_l l}{I-S.P_S}\right]\Big/\left[1-\frac{p_l l}{I-S.P_S}\right] \tag{5.2}$$

The derivation of this formulae is complex and can be found in Ballard et.al (1985) equations (6.15) to (6.28).

It is not possible to undertake the same process for the elasticity of substitution between savings and consumption due to the mathematical complexity involved. Instead, for a given savings elasticity estimate an iteration process must be undertaken to calculate the elasticity of substitution. The savings elasticity is given by:

$$\eta=\frac{\partial S}{p_S}\frac{p_S}{S}\approx\frac{\Delta S}{\Delta_S}\frac{p_S}{S} \tag{5.3}$$

Thus, for a given level of η, the savings elasticity, the elasticity of substitution may be calculated by using equation (4.2.15). The method is to change the price of saving by a given proportion from its initial value, thus giving a change in the level of saving. Thus, for a given σ_1 the savings elasticity, η, can be determined. It is thus a question of iterating on $\sigma 1$ until the calculated savings elasticity is equal to the required, empirical value.

Once the two elasticity of substitution parameters have been determined, it is relatively straightforward to calibrate the shift parameters in each household's utility function so that the labour supply, and savings match the data. This calibration process is complex mathematically, due to the complicated nature of the functions and requires several iterations to converge.

A large number of studies have been undertaken to calculate the wage elasticity. See Ballard et.al. (1985) or Borjas and Heckman (1978) for a survey. Estimates vary between male and female workers due to differences in participation patterns[10] . Estimates for the male elasticity range from -0.40

to 0, a range figure reduced by reviewing the econometric s of the studies to -0.07 to -0.19 by Borjas and Heckman (1978). Female estimates range from 0.2 to 1.6 with a cluster around 0.9. Taking the 'best' estimate for males to be -0.15 and the best estimate for females to be 0.9 and weighting by shares in total earnings gives a baseline value for the uncompensated wage elasticity of 0.15.

There is some variation in estimates of the savings elasticity but a central value of 0.4 is used from Boskin (1978) and sensitivity analysis is performed in the following section.

The estimates of wage and savings elasticity are not differentiated by household but when the elasticity of substitution values are derived and the shift parameters calibrated the parameters vary across households and are given, for the central cases, in Table 5.11.

A solution of the model for this baseline case, with a representative increase in energy taxes is now outlined in section 5.3.

5.3 An example solution to the model

To illustrate the model two simple scenarios are considered - energy taxes on production are increased by 100%[11] - Scenario 2 and by 200% - Scenario 3. For comparison purposes scenario 1 is the initial state of the model.

The basic results of the two scenarios are reported in table 5.12 and a more comprehensive listing can be found in appendix 5f.

It should be noted that the tax rises, although high in proportional terms are not high in absolute terms. Referring to table 5.3, a 100% rise in the tax rate on sector e3 (Coke, Oil production) raises the tax rate from around 10% to around 20%. All other things being equal this equates to a rise in the (pre-solution) price of sector e3 of 9.1%. Indeed, given that sector e1, is initially receiving a subsidy of 11.7%, scenario 1 simply removes this subsidy.

Table 5.12 - Example run of the model

	% change from baseline - Scenario 1	
	Scenario 2	Scenario 3
Wages	-0.36	-0.69
Interest Rate	-1.74	-3.27
Employment	-0.07	-0.15
Q	-0.23	-0.45
C	-0.59	-1.12
I	-0.46	-0.88
X	-0.04	-0.07
M	-0.01	-0.01
Qe1	-0.01	-0.02
Qe2	0.02	0.04
Qe3	-0.02	-0.04
Qe4	-0.03	-0.06
Qe5	-0.08	-0.15

It is quite difficult, due to the 'black-box' nature of the model to give a comprehensive, intuitive explanation for what is taking place. This is especially difficult given the simultaneity of the changes. However, an attempt will be made.

The increase in the producer price of energy means that firms substitute labour and capital for energy and raise prices in order to achieve normal profits. Thus demand for labour would tend to increase. However, this effect is outweighed by the effect on the household sector. Here, the increase in the price level changes the incentives to supply labour. The effect is markedly different across households. Lower income households increase their labour supply and higher income households reduce it (see Appendix 5f). This may be because energy takes up a larger amount of the budget share in lower income households.

However, because higher income households supply proportionally more labour and reduce their labour supply, overall labour supply falls, hence the wage must fall to achieve equilibrium. In addition, consumption and saving , fall as household income falls (due to the reduction in the wage level) which reduces output, putting further downward pressure on output. This effect is exacerbated by the reduction in output reducing the demand for capital and thus putting downward pressure on the interest rate that further reduces household income.

The overall effect is a reduction in output. Examining the reduction in output by each sector (again, given in appendix 5f) it is noticeable that the output of the alcohol and tobacco sector increases significantly, despite a fall in the output of all other sectors (barring small rises in the output of oil and gas extraction and raw materials). This is interesting as it mirrors the result of Chapter 3 (section 3.4.2) that showed an strong substitutability relationship between Energy (specified as Fuel in Chapter 3) and Alcohol. This is perhaps unsurprising as the same household demand structure was used in both models, but is reassuring none the less.

The focus now turns to the sensitivity of these results to the uncalibrated parameters.

5.4 Sensitivity Analysis

This section contains analysis of the sensitivity of the results of the model to changes in the uncalibrated parameters, namely the export and import elasticities, the uncompensated wage elasticity and the savings elasticity[12].
It is surmised that the model will be more sensitive to changes in the household parameters so a thorough examination of this issue is undertaken.

5.4.1 Trade elasticities

First however, the export and import elasticities are examined. Appendix 5g shows the model results for two scenarios. In each scenario the tax change imposed on the model is a tripling of the producer tax rates on energy. In appendix 5g, Scenario 1 is the baseline of the model with the central export and import elasticity parameters of -1.4 and 0.4 respectively. Scenario 2 imposes an export elasticity of -0.8 whilst Scenario 3 imposes an import elasticity of 0.8 (whilst returning the export elasticity to its baseline value of -1.4). The effect of the tax tripling with the central export/import parameters was given by Scenario 3 in section 5.3. For convenience, Table 5.13 reports the changes in key variables for the central case, and Scenarios 2 and 3 outlined above.

As can be seen from Table 5.13 changes in the major variables of output, Q, and consumption, C, are minimal. There is a small variation in the change in the level of exports and imports[13], as one would expect, but this has no discernible impact on the model.

It would seem fair to comment that the trade elasticities do not have a major impact on the model's results. This is almost certainly due to the simplistic structure imposed, explained in section 4.7 and justified in section 4.9.

Table 5.13 - Sensitivity to changes in the trade elasticities.

	Actual change in results for a tripling of producer energy taxation		
	Scenario 1 - Baseline parameters	Scenario 2 - Export elasticity = -0.8	Scenario 3 - Import elasticity = 0.8
Q	-4110.12	-4109.24	-4108.91
C	-3297.34	-3296.06	-3296.39
X	91.28	76.79	80.84
M	-17.36	-31.31	-27.97
w	-0.006	-0.006	-0.006
r	-0.0327	-0.327	-0.327
E	-0.0061	-0.0063	-0.0060

Attention is now turned to the household parameters. The effect of changes in the uncompensated wage elasticity of labour supply is detailed in section 5.4.2 and the effect of changes in the savings elasticity in section 5.4.3.

5.4.2 The uncompensated wage elasticity of labour supply.

The sensitivity analysis for changes in the uncompensated wage elasticity of labour supply can be found in Appendix 5h and Appendix 5i. In the first case, an uncompensated wage elasticity (UWES) of -0.3 was used (results in Appendix 5h) and in the second a UWES of -0.15. In each case the appropriate elasticities of substitution were calculated as outlined in section 5.2.3 and the remaining household parameters calibrated. The results are to be compared with the baseline run shown in Appendix 5f. In each case producer energy taxes were doubled and tripled.

An examination of the relevant data shows that there was significant variation due to the changes in the UWES, in absolute terms. For example, output falls by 4110 in the baseline case, by 4519 with UWES of -0.3 and by 4022 with an UWES of -0.05 when energy taxes are tripled. However, the difference in the percentage changes from the benchmark are small.

Table 5.14 - Effect of uncompensated wage elasticity of labour supply.

	Percentage changes from benchmark under differing estimates of UWES.		
	Baseline	UWES =-0.3	UWES=-0.05
Q	-0.45	-0.49	-0.44
C	-1.12	-1.25	-1.09
I	-0.88	-0.94	-0.89
X	0.07	0.06	0.06
M	-0.01	-0.02	-0.02
G revenue	7.68	7.61	7.68
LS	-0.15	-0.28	-0.06
w	-0.69	-0.60	-0.85
r	-3.27	-3.76	-2.93
E	-0.60	-0.60	-0.60
Producer receives price index	0.40	0.36	0.40
Producer pays price index	1.55	1.51	1.55
Consumption price index	0.28	0.26	0.29

Table 5.14 shows these percentage changes, in the three cases, from the base of the model (which is the same in each instance) when the larger of the two tax rises was imposed.

The results shown in Table 5.14 are sensible in that the higher the UWES, the more employment adjusts when faced by the tax rise, the more the wage rate must fall to compensate and thus, the more consumption and hence output fall. The increased fall in investment (saving) under UWES=-0.05 compared with the baseline is confusing but must be due to the interaction between income, expenditure and saving. Prices rise in all cases, with the lowest rise being when the UWES is highest. This is again consistent - if labour supply does not adjust such a great deal, it must be output prices that 'soak up' the tax rise.

Turning to the breakdown by household detailed in the appendices it is noticeable that in the base run the lower 5 households increase their labour supply and the top 5 households reduce it[14]. With an UWES of -0.3, the situation is the same but the changes are stronger, whilst with an UWES of -0.05, the lower 6 household increase labour supply and the top 4 only reduce it. Household net income falls for all households in all three cases and this change is greatest for all households with the high UWES.

It would thus appear that the model is relatively sensitive to changes in the uncompensated wage elasticity of supply. This no great surprise but it would seem that the changes are consistent with theory and that the chosen parameter of -0.15 is sensible.

5.4.3 The savings elasticity

The sensitivity analysis for changes in the savings elasticity can be found in Appendix 5j and Appendix 5k. Savings elasticities of 0.1 and 0.7 were imposed compared with the base case of 0.4. The uncompensated wage elasticity of supply remained at -0.15. Again, in each case the appropriate elasticities of substitution were calculated as outlined in section 5.2.3 and the remaining household parameters calibrated. The results are again to be compared with the baseline run shown in Appendix 5f and again in each case producer energy taxes were doubled and tripled.

Table 5.15 - Effect of savings elasticity

	Percentage changes from benchmark under differing estimates of UWES.		
	Baseline	SE =0.7	SE=0.1
Q	-0.45	-0.44	-0.46
C	-1.12	-1.20	-1.05
I	-0.88	-0.59	-1.17
X	0.07	0.06	0.06
M	-0.01	-0.02	-0.02
G revenue	7.68	7.66	7.70
LS	-0.15	-0.15	-0.15
w	-0.69	-0.68	-0.70
r	-3.27	-3.23	-3.32
E	-0.60	-0.60	-0.60
Producer receives price index	0.40	0.41	0.39
Producer pays price index	1.55	1.56	1.54
Consumption price index	0.28	0.28	0.28

In this case the effects are negligible except for the, to be expected differences, in consumption and investment. It will be noticed that the changes in investment reported in table 5.15 appear to be in the 'wrong direction'. One would expect the change in investment to be less, the lower the savings elasticity. The reason the changes are as they as, serves to demonstrate the 'black-box' nature of the model and the need for care in analysing its output. Although the overall price index rises, the price of investment actually falls from 1.023 in the bench mark case to 1.015 in each of the scenarios above. Thus, in this case a greater fall in investment when the savings elasticity is low is explained by the low response of savings (and hence investment) when the price of investment falls not compensating, to such an extent, for the fall in savings due to the fall in household income.

It is apparent from a close examination of the results that the savings elasticity is not a major cause for concern and that the bench mark estimate would seem sensible.

5.5 Conclusions

This chapter has examined and explained the data used in the model and detailed how it was transformed into an appropriate form. The chapter then covered the process of calibrating the model outlined in Chapter 4 to the data.

A simple run of the model for the benchmark parameters was examined and gave the result that an increase in the rate of producer taxes on energy had the effect of reducing output and the other main macroeconomic variables. This was due to a overall reduction in the labour supplied by households and is in line with the findings of the simplistic general equilibrium model in Chapter 2. At the same time, the output of the Alcohol and Tobacco sector rose, which is in line with the findings of the partial equilibrium analysis of Chapter 3 which showed a strong substitutability relationship between the Fuel and Alcohol and Tobacco sectors.

From a distributional point of view, this baseline run of the model showed that household labour supply increase for the lower end of the income distribution (and fell for the higher end) but hat all households suffered a fall in net income which coupled with the rise in consumer prices meant that all households suffered a net loss under the basic tax change (ignoring any environmental effects from changes in energy usage). Indeed such is the complexity of the model that direct environmental effects are not discernible - it is simply taken that a reduction in energy use is a desirable goal.

There were four main parameters that were not calibrated but were taken from empirical estimates - the price elasticity of exports, the price elasticity of imports, the uncompensated wage elasticity of labour supply and the savings elasticity. Sensitivity analysis was performed for these parameters to determine the effect of changes in their value on the basic results of the model.

This sensitivity analysis showed that the model was relatively insensitive to changes in the two trade elasticities. The model was shown to be relatively sensitive to the uncompensated wage elasticity of supply which was used to (indirectly) calibrate each of the 10 household utility functions. This was due to the differential effect of labour supply by households which is a major influence on the model. The level of this parameter, -0.15, used for the bench mark case, appeared to be sensible and will be used in the following chapter.

Turning to the savings elasticity, which again was used to calibrate the appropriate household sub-utility function, it was found that the effect of changes in this parameter was small. The major impact was a relatively minor change in the relative shares of consumption and investment with little effect on output or any of the other model's variables. This change appeared, at first glance, to be in the wrong direction given the changes in the savings elasticity parameter but may be explained by a fall in the price of investment[15] whilst overall prices rose.

The focus of Chapter 6, which presents a comprehensive selection of results from the model, is on revenue-neutrality and specifically which revenue returning instrument (from a choice of general producer taxes on output, producer taxes on labour inputs[16], consumption commodity taxation, corporation and income taxation and lump-sum transfers - an increase in transfer payments to households) produces the most efficient and equitable outcome. Efficiency is in terms of the entire economy - namely does output etc. fall by a lesser or greater amount whilst equity considerations concentrate on the effect on the different household groups of the income distribution.

Notes:

[1] Published by the Central Statistical Office (now Office for National Statistics), February 1995.
[2] Published by the Central Statistical Office (now Office for National Statistics), February 1995.
[3] The UK Input-Output tables are published every ten years approximately, between 2 and 5 years after the year they represent.
[4] Including the production function parameters as may be seen below.
[5] The way in which the DUM and IUM are transformed into the commodity by commodity DUM and IUM is detailed in the introduction to the tables.
[6] The row detailing Imports in the DUM is an aggregate of the IUM.
[7] State pensions are included in transfer payments.
[8] The omission of income tax allowances is explained in section 4.7.1 and is due to stability issues under general equilibrium.
[9] It is not possible to reformulate the model, by allowing initial producer prices to vary from unity, in order that (4.3.9) shows zero profits for all sectors. This is due to the inclusion of intermediate inputs.
[10]Female workers may be part time or a household's second income.
[11]An increase in energy taxes of 100% means that if the tax rate was 10% it will now be 20%, rather than 10% becoming 110%.
[12]It will be recalled from the previous section that it is empirical values for the uncompensated wage elasticity and the savings elasticity that are used to determine the two substitution elasticities in the household utility functions and hence calibrate the shift parameters.
[13]By referring to Appendix 5g it will be seen that the difference, when expressed as a percentage does not register at an level of 2 decimal places.
[14]Although the change in household 6 is marginal.
[15]This fall in the price of investment is simply due to the fact that whilst overall prices rose, prices in the sectors which comprise the composite investment good tended to fall.
[16]Equivalent to employer's National Insurance contributions.

Appendix 5– Key to Tables

a	Alcohol and Tobacco
c	Clothing
d	Durables
e1	Coal Extraction
e2	Oil and Gas Extraction
e3	Coke, Oil Production
e4	Electricity
e5	Gas
f	Food

g	Government
hd	Household Durables
o	Other
cm	Construction Materials
s	Services
bs	Business Services
t	Transport
z	Capital Goods
zm	Raw Materials

TI	Total Intermediate
C	Consumption
G	Government Expenditure
I	Investment
S	Stocks
FD	Final Demand
T	Total

M	Imports
T-S	Taxes – Subsides
YE	Employment Earnings
GP	Gross trading surplus

Appendix 5a – Domestic Use Matrix

	a	c	d	e1	e2	e3	e4	e5	f	g	hd	o	cm	s	bs	t	z	zm
a	412	0	0	0	2.3	0	0	0	294.2	20.9	0.6	0.4	12.7	211.2	55.9	52.5	143.7	3.2
c	0.4	1334.4	133.7	0	0	0	0	0	338.2	136.1	12.2	212.6	433.8	564.7	206.8	376	1129.9	72.2
d	0	18.5	503.8	0	0	0	1.1	0	98.5	88.8	23.7	43.4	438	395.5	255.6	629.3	333.2	41.3
e1	5.7	8.7	1.1	32.6	0	10.4	2317.1	0	32.4	0	0	26.6	125.6	0.1	0	12.2	38.1	438.5
e2	0	0	0	0	802.2	3547.9	0	1811.1	50	0	0	18.6	0	0	0	0	0.6	42.6
e3	6.8	4.1	6.8	0	0	731.3	693.8	1	382.5	39.5	12.5	108.9	226.5	398.2	96.8	1452	775.1	687.5
e4	47.9	94.7	36.4	181.2	0	11.4	11399.2	0	786.3	196.3	25.6	478.7	455.4	958.2	231.4	678	1198.6	696.2
e5	32.8	51.2	14	4.6	0	37.7	13.6	336.5	282.2	90.9	8.9	233.7	164.1	249.4	98.5	320.4	555	457.7
f	725.2	331.7	22.1	10	35.9	54.7	96.2	26.3	20175.2	245.3	11.9	301.4	352.3	795.4	346.3	451.3	3962.9	249.1
g	144.8	103.7	80	26.7	0	58.6	96.4	58.1	839.2	1650.1	53.5	741.6	464.3	2036.3	992.9	773.7	1038.7	397.9
hd	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
o	777	612.5	684.2	46.7	8.1	92.1	203.8	151.9	3695.1	666.1	153.1	4963	2696.5	4558.6	1687.3	3114.6	6123.4	1555.5
cm	60.2	72	61	24.3	14.4	4.9	23.2	1.7	682.3	67.7	857.5	696.5	6461.6	1541.4	147.6	593.3	1406.3	1063
s	564	545	366.6	72.1	257	186.1	438.2	196.7	4956.7	994.2	7137.3	3544.5	3971.4	27817.3	8262	6236.5	8890	7113.6
bs	316.6	460	317.4	89.7	60	65.2	99.2	75.8	2064.3	248.9	449	2962	2604.9	7927.6	7882.3	4436.3	5821.2	2015
t	236.2	255.5	212.3	218.1	1041.3	125.4	89.3	56	2271.6	339.7	145	1827.9	3671	3369.7	1813.3	10872.2	12782.2	1762.9
z	359.5	609.6	434.8	471.8	873.7	259.9	688.7	149.5	3187.8	247.4	120.3	3038.2	6499	2467.5	556.3	5621.2	12679	3348.1
zm	461.4	378.1	799.5	181.4	46.6	175.6	35.1	58	2394.5	194.5	14.3	4602.2	7226.2	2789.4	756.2	3713.8	10209	7088.6
TI	4150.6	4879.9	3673.9	1359.3	3141.6	5361.1	16194.9	2922.7	42531.2	5226.1	9025.3	23800.2	35803.5	56080.4	23389.2	39333.2	67087	27032.6
M	1070.2	3856.9	1382.2	166.4	1044.9	3324.6	1452.1	1982.9	7650.3	521	13.4	10848.4	5937.1	2645.4	1654	9910.8	9692.6	8342
T-S	286.9	172.3	102.4	-159.2	14.1	540.1	1962.1	541.6	2.1	699.4	7.3	653.7	535.5	4330.9	772.6	960.3	7963.3	1700.2
YE	1290.9	4676	2475.5	1853.4	869.1	674.9	2499.7	1497	20520	76202.8	0	16417.5	20634.3	43112	21290.8	27749.2	55988.5	12730.5
GP	1794.3	1248.9	555.3	154.7	6777.1	2285.6	2674.4	1324	13337.2	11222.5	26435.6	7911	18629.2	25864.6	6378	15422.4	20095.8	5818.4
T	8592.9	14840	8191.7	3380.7	11865.1	12205.4	24783.3	8274.6	84082.5	93899.7	35481.6	59684	81701.6	132147.4	54199.9	93672.8	160968.2	57894.6

	TI	C	G	I	S	X	FD	T
a	1209.7	4377.1	19.4	0	80.3	2906.4	7383.2	8592.9
c	4950.9	3679	588.2	0	-12.5	5634.2	9888.9	14839.8
d	2870.8	2458.3	735	1264.6	-46.2	909.2	5320.8	8191.7
e1	3049.2	312.4	82.5	0	-204.3	140.8	331.3	3380.6
e2	6273	0	0	0	-5	5597	5592	11865
e3	5623.4	2867.8	656.9	0	28	3029.3	6582	12205.4
e4	17475.5	6200.9	896.6	0	0	210.2	7307.7	24783.2
e5	2951.2	4805.6	525.3	0	-13	5.5	5323.4	8274.6
f	28193.3	44700.8	1053.3	0	130.1	9894.6	55778.9	83972.2
g	9556.6	9164.8	75079.3	0	0	47	84291	93847.6
hd	0	35481.6	0	0	0	0	35481.6	35481.6
o	31789.4	8251	4367.1	17	-25.4	15284.4	27894.1	59683.5
cm	13778.9	5927.5	5098.9	54049.7	833.2	2013.9	67923.2	104701.5
s	81549.1	39597	3826.3	594.7	0	5434	49451.9	131001
bs	37895.6	1020.9	3047.5	8067.9	0	4168	16304.4	54199.9
t	41089.7	16967.9	3236	7581.7	-376.5	25081	52490.1	93579.8
z	41612.2	67636.3	5044.2	13752.2	-536.9	33460.4	119356.4	160968.6
zm	41124.3	524.3	1536.7	324.3	-384.7	14770.2	16770.7	57895
TI	370992.7	253973.1	105793.2	85652.1	-532.9	128586.2	573471.7	967463.9
M	3881	43967.8	10091.3	21293.6	-585	2022	76789.8	80670.8
T-S	312358.2	42322.6	4633.5	4189.9	0	0	51146.1	363504.2
YE	167928.9	0	0	0	0	0	0	167928.9
GP	912260.3	0	0	0	0	0	0	912260.3
T	1788507	345650.5	112934	106775.7	-1117.9	133284.2	697526.5	2509033

Appendix 5b – Import Use Matrix

	a	c	d	e1	e2	e3	e4	e5	f	g	hd	o	cm	s	bs	t	z	zm
a	169.3	0	0	0	0	0	0	0	141.2	0	0	0.5	0	0	0	10.1	2.8	0
c	0	2803.5	225.2	0	0	0	0	0	122.2	5.9	0	276.1	37.6	71.2	5.8	116.2	313.2	43.8
d	0	0.3	17.7	0	0	0	0	0	26.2	0	0	0	62.7	12.2	0	44.3	6	0.6
e1	0	0	0	1	0	77.5	512.1	0	4.2	0	0	0.6	2	0	0	0.1	1.8	27.8
e2	0	0	0	0	74.9	2663.4	0	1889.1	36.8	0	0	13.9	0	0	0	0	0.5	31.5
e3	33.2	11	19.9	0	0	368.8	364.3	6.4	209.5	13.7	0	226.8	153.4	21	13.1	551.7	132.6	577.4
e4	0	0	0	0	0	0.1	234.5	0	1.5	0	0	0	0	0	0	0	0	0
e5	0.1	0.2	0	0	0	0.1	0.1	1.1	0.6	0	0	0.9	0.2	0	0	0.2	0.5	1.6
f	481.3	158.5	0.6	0	0	0.2	0	0	5147	0	0	226.9	0.3	0	0	29.4	5.1	18
g	1	1.3	1.3	0	0	0.1	1.7	1.5	5.9	411.3	0	13.2	3.2	66.1	1.5	31.3	14.1	2.6
hd	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
o	245.6	186.3	272.3	22.8	3.8	24.6	97.6	23.3	899.4	26.9	0	2486.3	784.5	224	44.9	1091.4	3539.2	520.3
cm	1.5	14.1	137.7	23.5	1.9	2.3	85.5	0.1	17.4	0	0	89.1	1103.2	111.3	1.9	174.2	155.2	65.7
s	1	4.6	1.6	0.1	4	3	4.3	2.8	23.9	28.7	0	26.5	18	1319.6	79.8	25.5	12.9	57
bs	19.3	31.6	22.7	9.1	5.2	3.5	5.3	4.9	87	5.7	13	127.4	118.4	444.8	1046.9	147.4	201.9	142.7
t	9.7	12.4	5.9	5.4	724.2	18.7	3.1	0.4	131.1	14.9	0.4	81.2	87	265.1	43.1	5761.6	612.4	99.1
z	3.2	40.9	155.4	38.2	222.7	4.9	141.5	43.5	212.3	9.3	0	266.7	899.4	75.1	12.7	1075.5	2830.9	192.4
zm	105	592.2	521.8	66.2	8.2	157.4	2.2	9.7	584.1	4.5	0	7012.3	2667.1	35	404.3	851.8	1863.4	6561.6
TI	1070.2	3856.9	1382.2	166.4	1044.9	3324.6	1452.1	1982.9	7650.3	521	13.4	10848.4	5937.1	2645.4	1654	9910.8	9692.6	8342
M	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T-S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
YE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T	1070.2	3856.9	1382.2	166.4	1044.9	3324.6	1452.1	1982.9	7650.3	521	13.4	10848.4	5937.1	2645.4	1654	9910.8	9692.6	8342

	TI	C	G	I	S	X	FD	T
a	323.9	2117	35.7	0	6	0	2158.7	2482.6
c	4020.6	7283.5	13.1	0	-4	25	7317.6	11338.2
d	170.1	1634.1	30.9	302.3	-11	10	1966.3	2136.4
e1	627.2	40	1	0	-31	0	10	637.2
e2	4710	0	0	0	-2	0	-2	4708
e3	2703	513.8	30.2	0	4	0	548	3251
e4	236	0	0	0	0	0	0	236
e5	5.7	0	0	0	0	0	0	5.7
f	6067.5	11300.9	471.5	0	24	50	11846.4	17913.9
g	556.1	646.2	631.7	0	0	0	1277.9	1834
hd	0	0	0	0	0	0	0	0
o	10493.3	6717.9	833.9	0	-42	43	7552.8	18046.1
cm	1984.5	454.2	54	260.1	-11	0	757.3	2741.8
s	1613.3	1153.7	378.4	0.4	0	0	1532.5	3145.7
bs	2436.9	30.8	813.5	0	0	0	844.2	3281.1
t	7875.8	10340.6	3511.9	5609.7	-226	25	19261.2	27137
z	6224.6	954.7	3211.1	15084.9	-154	35	19131.7	25356.3
zm	21446.6	780.6	74.4	36.2	-138	1834	2587.3	24033.9
TI	71495.2	43967.8	10091.3	21293.6	-585	2022	76789.8	148285
M	0	0	0	0	0	0	0	0
T-S	0	0	0	0	0	0	0	0
YE	0	0	0	0	0	0	0	0
GP	0	0	0	0	0	0	0	0
T	71495.2	43967.8	10091.3	21293.6	-585	2022	76789.8	148285

Appendix 5c – The Intermediate Use per unit output Matrix

	a	c	d	e1	e2	e3	e4	e5	f	g	hd	o	cm	s	bs	t	z	zm
a	0.068	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.000	0.000	0.000	0.000	0.002	0.001	0.001	0.001	0.000
c	0.000	0.279	0.044	0.000	0.000	0.000	0.000	0.000	0.006	0.002	0.000	0.008	0.006	0.005	0.004	0.005	0.009	0.002
d	0.000	0.001	0.064	0.000	0.000	0.000	0.000	0.000	0.002	0.001	0.001	0.001	0.006	0.003	0.005	0.007	0.002	0.001
e1	0.001	0.001	0.000	0.010	0.000	0.007	0.114	0.000	0.000	0.000	0.000	0.001	0.002	0.000	0.000	0.000	0.000	0.008
e2	0.000	0.000	0.000	0.000	0.074	0.509	0.000	0.447	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.001
e3	0.005	0.001	0.003	0.000	0.000	0.090	0.043	0.001	0.007	0.001	0.000	0.006	0.005	0.003	0.002	0.021	0.006	0.022
e4	0.006	0.006	0.004	0.054	0.000	0.001	0.469	0.000	0.009	0.002	0.001	0.008	0.006	0.007	0.004	0.007	0.007	0.012
e5	0.004	0.004	0.002	0.001	0.000	0.003	0.001	0.041	0.003	0.001	0.000	0.004	0.002	0.002	0.002	0.003	0.004	0.008
f	0.140	0.033	0.003	0.003	0.003	0.005	0.004	0.003	0.301	0.003	0.000	0.009	0.004	0.006	0.006	0.005	0.025	0.005
g	0.017	0.007	0.010	0.008	0.000	0.005	0.004	0.007	0.010	0.022	0.002	0.013	0.006	0.016	0.018	0.009	0.007	0.007
hd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
o	0.119	0.054	0.117	0.021	0.001	0.010	0.012	0.021	0.055	0.007	0.004	0.125	0.043	0.036	0.032	0.045	0.060	0.036
cm	0.007	0.006	0.024	0.014	0.001	0.001	0.004	0.000	0.008	0.001	0.024	0.013	0.093	0.013	0.003	0.008	0.010	0.020
s	0.066	0.037	0.045	0.021	0.022	0.016	0.018	0.024	0.059	0.011	0.201	0.060	0.049	0.221	0.154	0.067	0.055	0.124
bs	0.039	0.033	0.042	0.029	0.006	0.006	0.004	0.010	0.026	0.003	0.013	0.052	0.033	0.063	0.165	0.049	0.037	0.037
t	0.029	0.018	0.027	0.066	0.149	0.012	0.004	0.007	0.029	0.004	0.004	0.032	0.046	0.028	0.034	0.178	0.083	0.032
z	0.042	0.044	0.072	0.151	0.092	0.022	0.034	0.023	0.040	0.003	0.003	0.055	0.091	0.019	0.011	0.072	0.096	0.061
zm	0.066	0.065	0.161	0.073	0.005	0.027	0.002	0.008	0.035	0.002	0.000	0.195	0.121	0.021	0.021	0.049	0.075	0.236

Appendix 5d - The whole economy data

	Consumption	Government Expenditure	Capital Expenditure	Stocks	Exports	Imports - Final Demand	Intermediate Demand	Q=C+G+I+S+X-M+ID	Labour demand	Capital Demand	Energy Demand	e1	e2	e3	e4	e5
a	5060.27	51.56	0.00	1524.17	2718.48	2322.10	1004.88	8037.26	1290.88	1281.62	113.39	6.45	0.00	36.40	42.76	27.79
c	5389.43	581.13	0.00	4591.63	5445.76	10479.07	8814.52	14343.41	4675.95	892.09	151.46	9.90	0.00	13.80	84.45	43.30
d	3952.41	748.86	1880.25	-1024.75	888.95	1539.66	3102.92	8008.99	2475.47	396.65	69.88	1.27	0.00	24.27	32.50	11.84
e1	147.16	94.56	0.00	765.18	159.52	704.00	3366.47	3828.90	1753.44	110.49	203.68	38.10	0.00	0.04	161.63	3.91
e2	0.00	0.00	0.00	537.54	5572.06	4126.58	9829.02	11812.04	969.13	4840.81	873.13	0.00	873.13	0.00	0.00	0.00
e3	1412.33	624.21	0.00	779.80	2752.03	2476.19	7996.00	11088.19	674.92	1632.57	7324.62	99.57	6183.56	999.33	10.23	31.93
e4	2589.83	799.68	0.00	1835.48	187.49	-313.20	16379.40	22105.08	2499.74	1910.27	14553.68	3204.44	0.00	961.25	10376.49	11.50
e5	2007.06	443.19	0.00	1186.44	4.61	-506.24	2833.28	6980.82	1497.03	945.68	3975.32	0.00	3683.73	6.76	0.00	284.84
f	51199.69	1576.88	0.00	8421.48	10232.07	18400.94	33806.53	86835.71	20520.04	9526.61	1607.04	41.51	86.44	537.86	702.70	238.54
g	8750.27	66486.74	0.00	-1294.27	41.27	1129.27	9558.97	82413.71	76202.76	8016.09	300.05	0.00	0.00	48.32	175.05	76.68
hd	34268.48	0.00	0.00	1046.50	0.00	0.00	0.00	35314.98	0.00	18882.58	41.78	0.00	0.00	11.37	22.86	7.55
o	13350.61	5001.67	19.75	121.72	14698.64	16937.69	41141.51	57396.21	16417.52	5650.68	992.87	30.78	32.29	304.94	426.96	197.91
cm	6163.55	5106.33	66952.20	6912.10	1995.70	2158.87	18786.58	103757.59	20634.32	13306.54	1034.62	144.58	0.00	345.19	406.21	138.64
s	36147.74	3879.78	636.08	-12996.69	5014.16	2410.28	90608.79	120879.56	43111.98	18474.72	1445.95	0.08	0.00	380.84	854.64	210.39
bs	932.90	3467.62	8169.28	-4494.60	3743.34	2480.01	39339.28	48677.82	21290.82	4555.70	389.40	0.01	0.00	99.86	206.40	83.15
t	23872.71	6585.15	15770.60	-1852.32	24476.05	26054.21	48525.06	91323.04	27749.22	11016.01	2709.47	14.01	0.00	1820.28	604.70	270.49
z	61175.57	8024.69	34205.62	-3675.42	32525.46	24231.31	48446.75	156471.36	55988.48	14354.11	2408.73	45.24	1.10	824.60	1069.09	468.70
zm	1163.80	1512.62	398.91	-2950.78	13867.42	22306.21	62670.58	54356.34	12730.46	4155.98	2759.39	528.11	73.72	1149.15	620.94	387.46
TOTAL	257583.82	104984.68	128032.69	-566.79	124323.00	136936.94	446210.55	923631.01	310482.17	119949.21	40954.45	4164.05	10933.96	7564.23	15797.60	2494.61

Appendix 5e - The Almost Ideal Demand System

	1	2	3	4	5	6	7	8	9	10
I-Food	0.8716064	0.8731812	0.8767347	0.8381631	0.8690501	0.8738895	0.8741998	0.875726	0.8754844	0.8724721
I-Alcohol	-0.045749	-0.065277	-0.103607	-0.118271	-0.133828	-0.150434	-0.153999	-0.161805	-0.170268	-0.183191
I-Fuel	0.2475921	0.252817	0.2625142	0.2711206	0.2779876	0.2812732	0.2839687	0.2851917	0.2880339	0.29695
I-Clothing	-0.162133	-0.160024	-0.164058	-0.166473	-0.165524	-0.170909	-0.171061	-0.170595	-0.170226	-0.174162
I-Transport	-0.277702	-0.27555	-0.263658	-0.25351	-0.255868	-0.262248	-0.261775	-0.266525	-0.273387	-0.289598
I-Other	0.3588238	0.3662025	0.381181	0.3969764	0.3854121	0.403403	0.3870741	0.3892681	0.4112939	0.391652
I-Services	0.0075626	0.0086499	0.0108945	0.0319939	0.0227708	0.0250254	0.0415931	0.0487393	0.0390685	0.0858764
InP co-ef	0	0	0	0	0	0	0	0	0	0
	0.158315	0.153893	0.142738	0.142386	0.140374	0.133741	0.134202	0.131653	0.12987	0.129732
	Food	Alcohol	Fuel	Clothing	Transport	Other	Services	LOG Ex		
LogEx	-0.1385	0.0435	-0.0675	0.0446	0.0925	-0.0079	0.0333			
Food	-0.0576	0.063	-0.0946	0.0343	0.0558	-0.0566	0.0557	-0.1385	-0.03162	-0.00123
Alcohol	0.063	-0.077	0.0738	-0.0019	-0.0172	-0.0213	-0.0194	0.0435	0.018848	0.009468
Fuel	-0.0946	0.0738	0.0091	0.0172	-0.0188	0.0204	-0.0071	-0.0675	0.045399	0.036084
Clothing	0.0343	-0.0019	0.0172	0.0105	-0.0525	0.0422	-0.0498	0.0446	0.013561	0.004188
Transport	0.0558	-0.0172	-0.0188	-0.0525	0.0266	-0.0026	0.0087	0.0925	-0.03573	-0.00209
Other	-0.0566	-0.0211	0.0204	0.0422	-0.0026	0.0165	0.0012	-0.0079	0.017112	0.000785
Services	0.0557	-0.0194	-0.0071	-0.0499	0.0087	0.0011	0.0109	0.0333	-0.0275	-0.00144

Appendix: 5f Baseline Run of the model

Producer energy taxes, doubled (2) and tripled (3)

Run	1	2	3	1 to 2	2 to 3	1 to 3	%1-2	%2-3	%1-3
w	0.909091	0.905788	0.902839	-0.003303	-0.00295	-0.00625	-0.36%	-0.33%	-0.69%
r	1	0.982638	0.967272	-0.017362	-0.01537	-0.03273	-1.74%	-1.56%	-3.27%
Q	921786.9	919621.5	917676.8	-2165.381	-1944.74	-4110.12	-0.23%	-0.21%	-0.45%
Q P index	1	1.001995	1.003999	0.0019947	0.002005	0.003999	0.20%	0.20%	0.40%
Q P t index	1.051586	1.059724	1.067889	0.0081381	0.008164	0.016302	0.77%	0.77%	1.55%
C P Index	1.116322	1.117871	1.119446	0.0015484	0.001575	0.003124	0.14%	0.14%	0.28%
Consumption	293159.2	291422.6	289861.9	-1736.655	-1560.68	-3297.34	-0.59%	-0.54%	-1.12%
Government Expenditure	104994.2	104994.2	104994.2	0	0	0	0.00%	0.00%	0.00%
Capital Expenditure	104426.7	103943.5	103505.3	-483.1978	-438.234	-921.432	-0.46%	-0.42%	-0.88%
Stocks	3294.541	3294.541	3294.541	0	0	0	0.00%	0.00%	0.00%
Exports	128586.2	128632	128677.5	45.757306	45.52549	91.2828	0.04%	0.04%	0.07%
Imports - Final Demand	143322.9	143314.2	143305.5	-8.714485	-8.65009	-17.3646	-0.01%	-0.01%	-0.01%
G expenditure (£)	277885.3	278062.4	278249.5	177.15915	187.107	364.2662	0.06%	0.07%	0.13%
G revenue £	259782.9	269737.4	279740.5	9954.4481	10003.12	19957.57	3.83%	3.71%	7.68%
T L D	310481.9	310249.6	310021.6	-232.2458	-228.015	-460.261	-0.07%	-0.07%	-0.15%
HLD - Household labour supply									
1	207	207.2825	207.5559	0.2824458	0.273467	0.555913	0.14%	0.13%	0.27%
2	640	641.4579	642.8189	1.4579142	1.361033	2.818947	0.23%	0.21%	0.44%
3	3470	3478.776	3486.855	8.7762705	8.078453	16.85472	0.25%	0.23%	0.49%
4	10348	10367.98	10386.13	19.980412	18.14985	38.13026	0.19%	0.18%	0.37%
5	18551	18571.88	18590.5	20.884848	18.6154	39.50025	0.11%	0.10%	0.21%
6	28978	28977.49	28975.92	-0.510189	-1.56716	-2.07735	0.00%	-0.01%	-0.01%
7	37653	37632.36	37611.74	-20.63353	-20.6239	-41.2574	-0.05%	-0.05%	-0.11%
8	48300	48240.33	48183.14	-59.66254	-57.1988	-116.861	-0.12%	-0.12%	-0.24%
9	61274	61176.1	61082.92	-97.89788	-93.1779	-191.076	-0.16%	-0.15%	-0.31%
10	101061	100956	100854.1	-105.0092	-101.925	-206.935	-0.10%	-0.10%	-0.20%
HP -Consumption price index									
1	1.160835	1.163255	1.165643	0.0024194	0.002388	0.004807	0.21%	0.21%	0.41%
2	1.158564	1.161061	1.163526	0.0024972	0.002465	0.004962	0.22%	0.21%	0.43%
3	1.148448	1.151019	1.153556	0.0025711	0.002537	0.005108	0.22%	0.22%	0.44%
4	1.143039	1.145454	1.147846	0.0024147	0.002393	0.004807	0.21%	0.21%	0.42%
5	1.138112	1.140433	1.142739	0.0023204	0.002306	0.004626	0.20%	0.20%	0.41%
6	1.125859	1.12792	1.12998	0.0020614	0.00206	0.004122	0.18%	0.18%	0.37%
7	1.117076	1.118724	1.120394	0.0016485	0.00167	0.003319	0.15%	0.15%	0.30%
8	1.107481	1.10877	1.1101	0.0012886	0.00133	0.002619	0.12%	0.12%	0.24%
9	1.10145	1.102541	1.103684	0.0010909	0.001143	0.002234	0.10%	0.10%	0.20%
10	1.083802	1.084095	1.084486	0.0002937	0.000391	0.000685	0.03%	0.04%	0.06%
HNI - Household net income									
1	12646.23	12634.76	12624.62	-11.46906	-10.1373	-21.6064	-0.09%	-0.08%	-0.17%
2	15980.43	15946.47	15916.45	-33.96072	-30.0203	-63.981	-0.21%	-0.19%	-0.40%
3	21397.41	21334.66	21279.24	-62.75351	-55.4155	-118.169	-0.29%	-0.26%	-0.55%
4	26924.95	26824.22	26735.1	-100.7362	-89.113	-189.849	-0.37%	-0.33%	-0.71%
5	33964.3	33818.79	33689.65	-145.5034	-129.138	-274.641	-0.43%	-0.38%	-0.81%
6	41983.06	41782.21	41603.11	-200.8504	-179.102	-379.952	-0.48%	-0.43%	-0.91%
7	49606.74	49346.98	49114.81	-259.7622	-232.166	-491.929	-0.52%	-0.47%	-0.99%
8	59022.54	58687.78	58387.83	-334.7573	-299.948	-634.705	-0.57%	-0.51%	-1.08%
9	71663.94	71237.61	70855.17	-426.3249	-382.44	-808.765	-0.59%	-0.54%	-1.13%
10	121536.8	120790.5	120122.7	-746.3195	-667.749	-1414.07	-0.61%	-0.55%	-1.16%
QD - Output by sector									
Alcohol and Tobbacco	8038.751	8062.371	8088.364	23.619939	25.99308	49.61302	0.29%	0.32%	0.62%
Clothing	10013.31	9980.138	9952.082	-33.17323	-28.0561	-61.2293	-0.33%	-0.28%	-0.61%
Durables	77388.42	77211.7	77053.68	-176.719	-158.022	-334.741	-0.23%	-0.20%	-0.43%
Coal Extraction	3828.899	3828.599	3828.306	-0.300064	-0.29308	-0.59315	-0.01%	-0.01%	-0.02%
Oil and Gas Extraction	11812.04	11814.31	11816.56	2.2683851	2.25625	4.524635	0.02%	0.02%	0.04%
Coke, Oil Production	11088.18	11085.73	11083.35	-2.451149	-2.38592	-4.83707	-0.02%	-0.02%	-0.04%
Electricity	22105.07	22098.33	22091.73	-6.733126	-6.60139	-13.3345	-0.03%	-0.03%	-0.06%
Gas	6980.809	6975.525	6970.343	-5.284452	-5.182	-10.4665	-0.08%	-0.07%	-0.15%
Food	56290.51	55876.04	55491.67	-414.473	-384.367	-798.84	-0.74%	-0.69%	-1.42%
Government	79013.71	78968.27	78928.26	-45.43982	-40.0158	-85.4556	-0.06%	-0.05%	-0.11%
Household Durables	39382.92	39235.29	39104.01	-147.6293	-131.284	-278.914	-0.37%	-0.33%	-0.71%
Other	45684.05	45635.12	45592.63	-48.92442	-42.4885	-91.4129	-0.11%	-0.09%	-0.20%
Construction Materials	103756.8	103482.2	103233.6	-274.6501	-248.615	-523.265	-0.26%	-0.24%	-0.50%
Services	173169	172881.3	172623.3	-287.7821	-257.939	-545.721	-0.17%	-0.15%	-0.32%
Business Services	48677.7	48644.76	48615.08	-32.93216	-29.6857	-62.6178	-0.07%	-0.06%	-0.13%
Transport	48416.18	48126.54	47863.04	-289.6368	-263.501	-553.137	-0.60%	-0.55%	-1.14%
Capital Goods	125209.3	124778.6	124398.4	-430.698	-380.195	-810.893	-0.34%	-0.30%	-0.65%
Raw Materials	50931.23	50936.79	50942.43	5.5568461	5.643955	11.2008	0.01%	0.01%	0.02%

Appendix: 5g Export and Import elasticity sensitivity

Baseline (1): EE=-1.4, iE=0.4 EE=0.8 iE=0.8

	1	2	3	1 to 2	2 to 3	1 to 3	%1-2	%2-3	%1-3
w	0.909091	0.902842	0.902842	-0.006249	-7.4E-07	-0.00625	-0.69%	0.00%	-0.69%
r	1	0.967284	0.96728	-0.032716	-3.2E-06	-0.03272	-3.27%	0.00%	-3.27%
E	1	0.993702	0.993997	-0.006298	0.000295	-0.006	-0.63%	0.03%	-0.60%
Q	921786.9	917677.7	917678	-4109.244	0.335064	-4108.91	-0.45%	0.00%	-0.45%
Q P index	1	1.003998	1.003997						
Q P t index	1.051586	1.067887	1.067886						
C P Index	1.116322	1.119447	1.119447						
Consumption	293159.3	289863.2	289862.9	-3296.059	-0.32688	-3296.39	-1.12%	0.00%	-1.12%
Government Expenditure	104994.2	104994.2	104994.2	0	0	0	0.00%	0.00%	0.00%
Capital Expenditure	104426.7	103505.4	103505.4	-921.289	-0.05358	-921.343	-0.88%	0.00%	-0.88%
Stocks	3294.541	3294.541	3294.541	0	0	0	0.00%	0.00%	0.00%
Exports	128586.2	128663	128667	76.786421	4.060374	80.84679	0.06%	0.00%	0.06%
Imports - Final Demand	143322.9	143291.6	143294.9	-31.3175	3.344844	-27.9727	-0.02%	0.00%	-0.02%
G expenditure (£)	277885.3	278249.7	278249.6						
G revenue £	259782.9	279741.2	279741.1						
T L D	310481.9	310021.8	310021.7	-460.1485	-0.01939	-460.168	-0.15%	0.00%	-0.15%
HLD - Household labour supply									
1	207	207.556	207.556	0.5559476	-4.5E-06	0.555943	0.27%	0.00%	0.27%
2	640	642.8187	642.8188	2.8186659	9.57E-05	2.818762	0.44%	0.00%	0.44%
3	3470	3486.852	3486.853	16.85203	0.000844	16.85287	0.49%	0.00%	0.49%
4	10348	10386.12	10386.13	38.123121	0.002308	38.12543	0.37%	0.00%	0.37%
5	18551	18590.49	18590.5	39.492977	0.002657	39.49563	0.21%	0.00%	0.21%
6	28978	28975.93	28975.93	-2.07404	0.000156	-2.07388	-0.01%	0.00%	-0.01%
7	37653	37611.75	37611.75	-41.24561	-0.00193	-41.2475	-0.11%	0.00%	-0.11%
8	48300	48183.17	48183.16	-116.8332	-0.00631	-116.839	-0.24%	0.00%	-0.24%
9	61274	61082.97	61082.96	-191.0322	-0.01041	-191.043	-0.31%	0.00%	-0.31%
10	101061	100854.1	100854.1	-206.9066	-0.00681	-206.913	-0.20%	0.00%	-0.20%
HP -Consumption price index									
1	1.160835	1.165643	1.165643	0.0048077	-5.2E-08	0.004808	0.41%	0.00%	0.41%
2	1.158564	1.163526	1.163526	0.004962	-5.2E-08	0.004962	0.43%	0.00%	0.43%
3	1.148448	1.153557	1.153557	0.0051085	-5.1E-08	0.005108	0.44%	0.00%	0.44%
4	1.143039	1.147847	1.147846	0.0048078	-8.7E-08	0.004808	0.42%	0.00%	0.42%
5	1.138112	1.142739	1.142739	0.0046269	-1.1E-07	0.004627	0.41%	0.00%	0.41%
6	1.125859	1.129981	1.129981	0.0041222	-1.4E-07	0.004122	0.37%	0.00%	0.37%
7	1.117076	1.120395	1.120395	0.0033199	-2.1E-07	0.00332	0.30%	0.00%	0.30%
8	1.107481	1.110101	1.110101	0.0026199	-2.6E-07	0.00262	0.24%	0.00%	0.24%
9	1.10145	1.103685	1.103685	0.0022352	-2.9E-07	0.002235	0.20%	0.00%	0.20%
10	1.083802	1.084488	1.084488	0.0006867	-4.1E-07	0.000686	0.06%	0.00%	0.06%
HNI - Household net income									
1	12646.23	12624.63	12624.63	-21.59867	-0.00217	-21.6008	-0.17%	0.00%	-0.17%
2	15980.43	15916.47	15916.46	-63.95814	-0.00643	-63.9646	-0.40%	0.00%	-0.40%
3	21397.41	21279.29	21279.28	-118.1238	-0.01247	-118.136	-0.55%	0.00%	-0.55%
4	26924.95	26735.18	26735.16	-189.7729	-0.02058	-189.793	-0.70%	0.00%	-0.70%
5	33964.3	33689.77	33689.74	-274.5306	-0.02948	-274.56	-0.81%	0.00%	-0.81%
6	41983.06	41603.26	41603.22	-379.8016	-0.03967	-379.841	-0.90%	0.00%	-0.90%
7	49606.75	49115.01	49114.96	-491.7381	-0.05019	-491.788	-0.99%	0.00%	-0.99%
8	59022.54	58388.08	58388.01	-634.4659	-0.06305	-634.529	-1.07%	0.00%	-1.08%
9	71663.95	70855.48	70855.4	-808.466	-0.0791	-808.545	-1.13%	0.00%	-1.13%
10	121536.8	120123.3	120123.1	-1413.553	-0.13831	-1413.69	-1.16%	0.00%	-1.16%
QD - Output by sector									
Alcohol and Tobbacco	8038.752	8088.302	8088.33	49.550315	0.027718	49.57803	0.62%	0.00%	0.62%
Clothing	10013.31	9952.407	9952.347	-60.90519	-0.05933	-60.9645	-0.61%	0.00%	-0.61%
Durables	77388.42	77054.01	77054.08	-334.4097	0.067466	-334.342	-0.43%	0.00%	-0.43%
Coal Extraction	3828.899	3828.35	3828.34	-0.549079	-0.00992	-0.559	-0.01%	0.00%	-0.01%
Oil and Gas Extraction	11812.04	11816.37	11816.45	4.3366468	0.07054	4.407187	0.04%	0.00%	0.04%
Coke, Oil Production	11088.18	11083.31	11083.33	-4.872837	0.022364	-4.85047	-0.04%	0.00%	-0.04%
Electricity	22105.07	22091.73	22091.73	-13.33629	0.001385	-13.3349	-0.06%	0.00%	-0.06%
Gas	6980.809	6970.342	6970.343	-10.46675	9.91E-05	-10.4666	-0.15%	0.00%	-0.15%
Food	56290.51	55492.48	55492.3	-798.0343	-0.17598	-798.21	-1.42%	0.00%	-1.42%
Government	79013.71	78928.46	78928.41	-85.25044	-0.04964	-85.3001	-0.11%	0.00%	-0.11%
Household Durables	39382.93	39104.29	39104.23	-278.6328	-0.06164	-278.694	-0.71%	0.00%	-0.71%
Other	45684.05	45592.57	45592.64	-91.47587	0.072607	-91.4033	-0.20%	0.00%	-0.20%
Construction Materials	103756.8	103233.7	103233.7	-523.1407	-0.03116	-523.172	-0.50%	0.00%	-0.50%
Services	173169	172623.1	172623.2	-545.9061	0.09553	-545.811	-0.32%	0.00%	-0.32%
Business Services	48677.7	48614.93	48614.98	-62.76702	0.053459	-62.7136	-0.13%	0.00%	-0.13%
Transport	48416.18	47862.96	47863.02	-553.2219	0.055393	-553.167	-1.14%	0.00%	-1.14%
Capital Goods	125209.3	124397.4	124397.7	-811.8736	0.311721	-811.562	-0.65%	0.00%	-0.65%
Raw Materials	50931.23	50942.94	50942.89	11.712028	-0.05555	11.65648	0.02%	0.00%	0.02%

Appendix: 5h Uncompensated wage elasticity sensitivity

Baseline (1): UWES=-0.15,(2) UWES=-0.3, Et=2x ,(3) UWES=-0.3, Et=3x (3)

	1	2	3	1 to 2	2 to 3	1 to 3	%1-2	%2-3	%1-3
w	0.909091	0.906235	0.903649	-0.002856	-0.00259	-0.00544	-0.31%	-0.29%	-0.60%
r	1	0.980158	0.962423	-0.019842	-0.01774	-0.03758	-1.98%	-1.81%	-3.76%
E	1	0.99699	0.993997	-0.00301	-0.00299	-0.006	-0.30%	-0.30%	-0.60%
Q	921783.6	919417.1	917264.6	-2366.52	-2152.5	-4519.02	-0.26%	-0.23%	-0.49%
Q P index	1	1.001785	1.003561	0.001785	0.001776	0.003561	0.18%	0.18%	0.36%
Q P t index	1.051586	1.059521	1.067466	0.0079348	0.007945	0.01588	0.75%	0.75%	1.51%
C P Index	1.116333	1.117764	1.119222	0.0014309	0.001458	0.002889	0.13%	0.13%	0.26%
Consumption	293158	291246.5	289506.8	-1911.5	-1739.69	-3651.19	-0.65%	-0.60%	-1.25%
Government Expenditure	104994.2	104994.2	104994.2	0	0	0	0.00%	0.00%	0.00%
Capital Expenditure	104424.7	103915.1	103448	-509.5796	-467.068	-976.647	-0.49%	-0.45%	-0.94%
Stocks	3294.541	3294.541	3294.541	0	0	0	0.00%	0.00%	0.00%
Exports	128586.2	128626.7	128667	40.521334	40.32546	80.84679	0.03%	0.03%	0.06%
Imports - Final Demand	143322.9	143308.9	143294.9	-14.03778	-13.9349	-27.9727	-0.01%	-0.01%	-0.02%
G expenditure (£)	277885.3	278061.4	278243.2	176.16394	181.7411	357.905	0.06%	0.07%	0.13%
G revenue £	259773.3	269636.4	279534.9	9863.086	9898.485	19761.57	3.80%	3.67%	7.61%
T L D - Total labour supply	310481.4	310046.2	309618.5	-435.1376	-427.763	-862.9	-0.14%	-0.14%	-0.28%
HLD - Household labour supply									
1	207	207.1537	207.305	0.1536842	0.151292	0.304976	0.07%	0.07%	0.15%
2	640	641.1369	642.1948	1.1369185	1.057848	2.194766	0.18%	0.16%	0.34%
3	3470	3477.182	3483.758	7.1818278	6.576519	13.75835	0.21%	0.19%	0.40%
4	10348	10363	10376.42	14.997933	13.42418	28.42211	0.14%	0.13%	0.27%
5	18551	18561.85	18570.84	10.845699	8.995313	19.84101	0.06%	0.05%	0.11%
6	28978	28959.71	28940.89	-18.29091	-18.8221	-37.113	-0.06%	-0.06%	-0.13%
7	37653	37608.82	37565.15	-44.18465	-43.6606	-87.8452	-0.12%	-0.12%	-0.23%
8	48300	48208.31	48119.52	-91.68772	-88.7952	-180.483	-0.19%	-0.18%	-0.37%
9	61274	61133.89	60998.87	-140.115	-135.013	-275.128	-0.23%	-0.22%	-0.45%
10	101061	100885.2	100713.5	-175.7882	-171.677	-347.465	-0.17%	-0.17%	-0.34%
HP - Consumption price index									
1	1.160835	1.163226	1.165586	0.002391	0.002359	0.00475	0.21%	0.20%	0.41%
2	1.158564	1.161033	1.163469	0.0024688	0.002436	0.004905	0.21%	0.21%	0.42%
3	1.148448	1.150991	1.1535	0.0025429	0.002509	0.005052	0.22%	0.22%	0.44%
4	1.143039	1.145406	1.147751	0.002367	0.002345	0.004712	0.21%	0.20%	0.41%
5	1.138112	1.140372	1.142617	0.0022597	0.002245	0.004505	0.20%	0.20%	0.40%
6	1.125899	1.127882	1.129863	0.001983	0.001981	0.003964	0.18%	0.18%	0.35%
7	1.117113	1.118649	1.120206	0.0015356	0.001557	0.003092	0.14%	0.14%	0.28%
8	1.107495	1.108642	1.10983	0.001147	0.001188	0.002335	0.10%	0.11%	0.21%
9	1.101435	1.102368	1.103354	0.0009338	0.000985	0.001919	0.08%	0.09%	0.17%
10	1.083816	1.083887	1.084055	7.125E-05	0.000168	0.000239	0.01%	0.02%	0.02%
HNI - Household net income									
1	12646.23	12633.15	12621.47	-13.07339	-11.6807	-24.7541	-0.10%	-0.09%	-0.20%
2	15980.43	15941.72	15907.12	-38.71213	-34.5918	-73.304	-0.24%	-0.22%	-0.46%
3	21397.41	21326.22	21262.57	-71.19737	-63.6445	-134.842	-0.33%	-0.30%	-0.63%
4	26924.95	26811.78	26710.31	-113.1692	-101.476	-214.645	-0.42%	-0.38%	-0.80%
5	33964.3	33802.15	33656.2	-162.1458	-145.953	-308.099	-0.48%	-0.43%	-0.91%
6	41983.06	41761.75	41561.52	-221.313	-200.228	-421.541	-0.53%	-0.48%	-1.00%
7	49606.74	49322.09	49063.98	-284.6534	-258.109	-542.762	-0.57%	-0.52%	-1.09%
8	59022.54	58657.48	58325.61	-365.0606	-331.87	-696.93	-0.62%	-0.57%	-1.18%
9	71663.94	71199.58	70776.94	-464.364	-422.642	-887.006	-0.65%	-0.59%	-1.24%
10	121536.8	120714.3	119967.9	-822.5219	-746.437	-1568.96	-0.68%	-0.62%	-1.29%
QD - Output by sector									
Alcohol and Tobbacco	8035.671	8054.939	8076.428	19.267841	21.48903	40.75687	0.24%	0.27%	0.51%
Clothing	10013.05	9974.32	9940.566	-38.72541	-33.754	-72.4795	-0.39%	-0.34%	-0.72%
Durables	77387.92	77197.56	77025.06	-190.355	-172.497	-362.852	-0.25%	-0.22%	-0.47%
Coal Extraction	3828.943	3828.662	3828.386	-0.281732	-0.27525	-0.55698	-0.01%	-0.01%	-0.01%
Oil and Gas Extraction	11812.04	11814.25	11816.45	2.2094898	2.197697	4.407187	0.02%	0.02%	0.04%
Coke, Oil Production	11088.61	11086.16	11083.78	-2.446362	-2.38472	-4.83109	-0.02%	-0.02%	-0.04%
Electricity	22105.84	22099.13	22092.54	-6.712249	-6.5871	-13.2994	-0.03%	-0.03%	-0.06%
Gas	6981.409	6976.141	6970.97	-5.268223	-5.17088	-10.4391	-0.08%	-0.07%	-0.15%
Food	56292.7	55853.25	55443.43	-439.4555	-409.82	-849.275	-0.78%	-0.73%	-1.51%
Government	79013.77	78962.66	78916.81	-51.11599	-45.8434	-96.9594	-0.06%	-0.06%	-0.12%
Household Durables	39383.08	39218.73	39070.3	-164.3585	-148.424	-312.782	-0.42%	-0.38%	-0.79%
Other	45684.12	45628.34	45578.82	-55.77389	-49.5182	-105.292	-0.12%	-0.11%	-0.23%
Construction Materials	103755.8	103464.8	103198.4	-291.0487	-266.358	-557.407	-0.28%	-0.26%	-0.54%
Services	173169	172851.5	172563	-317.5422	-288.413	-605.956	-0.18%	-0.17%	-0.35%
Business Services	48677.57	48642.51	48610.54	-35.05474	-31.9733	-67.0281	-0.07%	-0.07%	-0.14%
Transport	48413.42	48099.86	47811.97	-313.5578	-287.892	-601.45	-0.65%	-0.60%	-1.24%
Capital Goods	125209.5	124727.5	124294.5	-481.9558	-433.008	-914.964	-0.38%	-0.35%	-0.73%
Raw Materials	50931.23	50936.89	50942.62	5.6544436	5.736237	11.39068	0.01%	0.01%	0.02%

Appendix: 5i Uncompensated wage elasticity sensitivity

Baseline (1): UWES=-0.15,(2) UWES=-0.05, Et=2x ,(3) UWES=-0.05, Et=3x (3)

	1	2	3	1 to 2	2 to 3	1 to 3	%1-2	%2-3	%1-3
w	0.909091	0.904962	0.901321	-0.004129	-0.00364	-0.00777	-0.45%	-0.40%	-0.85%
r	1	0.984406	0.970717	-0.015594	-0.01369	-0.02928	-1.56%	-1.39%	-2.93%
E	1	0.99699	0.993997	-0.00301	-0.00299	-0.006	-0.30%	-0.30%	-0.60%
Q	921789.4	919658.2	917766.4	-2131.201	-1891.74	-4022.94	-0.23%	-0.21%	-0.44%
Q P index	1	1.001979	1.004004	0.0019793	0.002025	0.004004	0.20%	0.20%	0.40%
Q P t index	1.051586	1.059708	1.06789	0.0081219	0.008182	0.016304	0.77%	0.77%	1.55%
C P Index	1.116319	1.117929	1.119568	0.00161	0.001639	0.003249	0.14%	0.15%	0.29%
Consumption	293161.9	291466	289959.7	-1695.978	-1506.25	-3202.23	-0.58%	-0.52%	-1.09%
Government Expenditure	104994.2	104994.2	104994.2	0	0	0	0.00%	0.00%	0.00%
Capital Expenditure	104426.5	103936.7	103497	-489.7814	-439.743	-929.524	-0.47%	-0.42%	-0.89%
Stocks	3294.541	3294.541	3294.541	0	0	0	0.00%	0.00%	0.00%
Exports	128586.2	128626.7	128667	40.521334	40.32546	80.84679	0.03%	0.03%	0.06%
Imports - Final Demand	143322.9	143308.9	143294.9	-14.03778	-13.9349	-27.9727	-0.01%	-0.01%	-0.02%
G expenditure (£)	277885.3	278033.2	278198.4	147.95378	165.1532	313.107	0.05%	0.06%	0.11%
G revenue £	259781.3	269725.4	279733.7	9944.1114	10008.27	19952.38	3.83%	3.71%	7.68%
T L D - Total labour supply	310483.1	310385.1	310290	-98.01483	-95.1136	-193.128	-0.03%	-0.03%	-0.06%
HLD - Household labour supply									
1	207	207.3786	207.7415	0.3785751	0.362975	0.74155	0.18%	0.18%	0.36%
2	640	641.7004	643.2858	1.7004224	1.585389	3.285812	0.27%	0.25%	0.51%
3	3470	3479.993	3489.194	9.9932787	9.20039	19.19367	0.29%	0.26%	0.55%
4	10348	10371.66	10393.23	23.656871	21.57417	45.23104	0.23%	0.21%	0.44%
5	18551	18578.77	18603.91	27.77077	25.13907	52.90984	0.15%	0.14%	0.29%
6	28978	28988.57	28997.74	10.566992	9.176054	19.74305	0.04%	0.03%	0.07%
7	37653	37646.61	37640	-6.385304	-6.60981	-12.9951	-0.02%	-0.02%	-0.03%
8	48300	48259.07	48220.6	-40.92503	-38.4742	-79.3992	-0.08%	-0.08%	-0.16%
9	61274	61200.62	61132.12	-73.38146	-68.4956	-141.877	-0.12%	-0.11%	-0.23%
10	101061	101010.7	100962.2	-50.26012	-48.572	-98.8321	-0.05%	-0.05%	-0.10%
HP - Consumption price index									
1	1.160835	1.163269	1.165672	0.0024339	0.002403	0.004837	0.21%	0.21%	0.42%
2	1.158564	1.161076	1.163555	0.0025117	0.00248	0.004991	0.22%	0.21%	0.43%
3	1.148448	1.151033	1.153585	0.0025854	0.002552	0.005138	0.23%	0.22%	0.45%
4	1.143039	1.145478	1.147896	0.002439	0.002418	0.004857	0.21%	0.21%	0.42%
5	1.138112	1.140463	1.142802	0.0023513	0.002338	0.00469	0.21%	0.21%	0.41%
6	1.125859	1.12796	1.130063	0.0021016	0.002102	0.004204	0.19%	0.19%	0.37%
7	1.117076	1.118782	1.120513	0.0017062	0.001731	0.003437	0.15%	0.15%	0.31%
8	1.10746	1.108821	1.110227	0.0013608	0.001406	0.002767	0.12%	0.13%	0.25%
9	1.101429	1.1026	1.103827	0.0011707	0.001227	0.002398	0.11%	0.11%	0.22%
10	1.083812	1.08422	1.08473	0.0004075	0.00051	0.000918	0.04%	0.05%	0.08%
HNI - Household net income									
1	12646.23	12635.81	12626.68	-10.41906	-9.12646	-19.5455	-0.08%	-0.07%	-0.15%
2	15980.43	15949.56	15922.53	-30.86253	-27.0363	-57.8988	-0.19%	-0.17%	-0.36%
3	21397.41	21339.24	21288.39	-58.17813	-50.8498	-109.028	-0.27%	-0.24%	-0.51%
4	26924.95	26828.91	26744.91	-96.04728	-83.994	-180.041	-0.36%	-0.31%	-0.67%
5	33964.3	33823.03	33699.17	-141.2683	-123.861	-265.129	-0.42%	-0.37%	-0.78%
6	41983.06	41784.23	41609.19	-198.8339	-175.041	-373.875	-0.47%	-0.42%	-0.89%
7	49606.74	49348.29	49120.28	-258.4491	-228.013	-486.463	-0.52%	-0.46%	-0.98%
8	59022.54	58687.96	58392.11	-334.5822	-295.846	-630.428	-0.57%	-0.50%	-1.07%
9	71663.94	71237.81	70860.62	-426.129	-377.19	-803.319	-0.59%	-0.53%	-1.12%
10	121536.8	120810.7	120169.5	-726.0945	-641.232	-1367.33	-0.60%	-0.53%	-1.13%
QD - Output by sector									
Alcohol and Tobbacco	8035.664	8060.373	8087.785	24.708515	27.41288	52.1214	0.31%	0.34%	0.65%
Clothing	10013.26	9981.52	9955.345	-31.7446	-26.1751	-57.9197	-0.32%	-0.26%	-0.58%
Durables	77388.36	77211.52	77055.28	-176.8477	-156.239	-333.087	-0.23%	-0.20%	-0.43%
Coal Extraction	3828.914	3828.63	3828.353	-0.283937	-0.27711	-0.56105	-0.01%	-0.01%	-0.01%
Oil and Gas Extraction	11812.04	11814.25	11816.45	2.2094898	2.197697	4.407187	0.02%	0.02%	0.04%
Coke, Oil Production	11088.33	11085.86	11083.46	-2.467529	-2.40259	-4.87012	-0.02%	-0.02%	-0.04%
Electricity	22105.33	22098.58	22091.96	-6.751061	-6.61987	-13.3709	-0.03%	-0.03%	-0.06%
Gas	6981.015	6975.717	6970.52	-5.298302	-5.19627	-10.4946	-0.08%	-0.07%	-0.15%
Food	56290.63	55882.38	55506.15	-408.2498	-376.24	-784.489	-0.73%	-0.67%	-1.39%
Government	79013.72	78969.67	78931.5	-44.05005	-38.1697	-82.2198	-0.06%	-0.05%	-0.10%
Household Durables	39382.94	39239.31	39113.33	-143.6362	-125.977	-269.613	-0.36%	-0.32%	-0.68%
Other	45684.05	45636.7	45596.32	-47.35893	-40.3785	-87.7374	-0.10%	-0.09%	-0.19%
Construction Materials	103756.7	103479.3	103230.7	-277.4481	-248.559	-526.007	-0.27%	-0.24%	-0.51%
Services	173169.1	172888.1	172639.3	-281.0162	-248.812	-529.828	-0.16%	-0.14%	-0.31%
Business Services	48677.68	48644.37	48614.66	-33.31136	-29.7106	-63.0219	-0.07%	-0.06%	-0.13%
Transport	48421.07	48136.62	47880.22	-284.4475	-256.403	-540.851	-0.59%	-0.53%	-1.12%
Capital Goods	125209.3	124788.3	124422.2	-421.0228	-366.099	-787.122	-0.34%	-0.29%	-0.63%
Raw Materials	50931.23	50937.05	50942.96	5.8155278	5.911177	11.7267	0.01%	0.01%	0.02%

Appendix: 5j Uncompensated wage elasticity sensitivity

Baseline (1): SE=0.4,(2) SE=0.7, Et=2x ,(3) SE=0.7, Et=3x (3)

	1	2	3	1 to 2	2 to 3	1 to 3	%1-2	%2-3	%1-3
w	0.909091	0.905839	0.902934	-0.003252	-0.0029	-0.00616	-0.36%	-0.32%	-0.68%
r	1	0.982892	0.967746	-0.017108	-0.01515	-0.03225	-1.71%	-1.54%	-3.23%
E	1	0.99699	0.993997	-0.00301	-0.00299	-0.006	-0.30%	-0.30%	-0.60%
Q	921783	919666.1	917765	-2116.91	-1901.13	-4018.04	-0.23%	-0.21%	-0.44%
Q P index	1	1.002047	1.004096	0.0020469	0.002049	0.004096	0.20%	0.20%	0.41%
Q P t index	1.051587	1.059774	1.067979	0.0081874	0.008205	0.016393	0.78%	0.77%	1.56%
C P Index	1.116883	1.118453	1.120047	0.0015705	0.001594	0.003164	0.14%	0.14%	0.28%
Consumption	293155.2	291309.4	289644.5	-1845.809	-1664.91	-3510.72	-0.63%	-0.57%	-1.20%
Government Expenditure	104994.2	104994.2	104994.2	0	0	0	0.00%	0.00%	0.00%
Capital Expenditure	104426.8	104101.2	103810.7	-325.6598	-290.484	-616.144	-0.31%	-0.28%	-0.59%
Stocks	3294.541	3294.541	3294.541	0	0	0	0.00%	0.00%	0.00%
Exports	128586.2	128626.7	128667	40.521334	40.32546	80.84679	0.03%	0.03%	0.06%
Imports - Final Demand	143322.9	143308.9	143294.9	-14.03778	-13.9349	-27.9727	-0.01%	-0.01%	-0.02%
G expenditure (£)	277885.3	278068.2	278260.4	182.96507	192.1586	375.1236	0.07%	0.07%	0.13%
G revenue £	259781.5	269712.1	279685.7	9930.5663	9973.615	19904.18	3.82%	3.70%	7.66%
T L D - Total labour supply	310480.2	310249.7	310021.9	-230.5564	-227.823	-458.379	-0.07%	-0.07%	-0.15%
HLD - Household labour supply									
1	206.9999	207.2824	207.5558	0.282466	0.273419	0.555885	0.14%	0.13%	0.27%
2	640	641.4492	642.8025	1.4492177	1.353293	2.802511	0.23%	0.21%	0.44%
3	3470	3478.703	3486.717	8.703297	8.014115	16.71741	0.25%	0.23%	0.48%
4	10348	10367.78	10385.74	19.775852	17.96833	37.74418	0.19%	0.17%	0.36%
5	18551	18571.62	18590.01	20.624953	18.38358	39.00854	0.11%	0.10%	0.21%
6	28978	28977.37	28975.7	-0.625837	-1.67128	-2.29711	0.00%	-0.01%	-0.01%
7	37653	37632.36	37611.74	-20.63932	-20.6237	-41.263	-0.05%	-0.05%	-0.11%
8	48300	48240.59	48183.64	-59.40812	-56.9515	-116.36	-0.12%	-0.12%	-0.24%
9	61274	61176.58	61083.87	-97.41873	-92.7116	-190.13	-0.16%	-0.15%	-0.31%
10	101061	100955.9	100854.1	-105.0589	-101.857	-206.916	-0.10%	-0.10%	-0.20%
HP - Consumption price index									
1	1.16106	1.163483	1.165874	0.0024236	0.002391	0.004815	0.21%	0.21%	0.41%
2	1.158788	1.161289	1.163757	0.0025014	0.002468	0.004969	0.22%	0.21%	0.43%
3	1.148666	1.151242	1.153782	0.0025752	0.00254	0.005115	0.22%	0.22%	0.45%
4	1.143379	1.145801	1.148198	0.0024216	0.002398	0.004819	0.21%	0.21%	0.42%
5	1.13852	1.140849	1.143161	0.0023291	0.002312	0.004642	0.20%	0.20%	0.41%
6	1.126291	1.128363	1.130432	0.0020725	0.002068	0.004141	0.18%	0.18%	0.37%
7	1.117681	1.119345	1.121028	0.0016642	0.001682	0.003346	0.15%	0.15%	0.30%
8	1.108145	1.109453	1.110798	0.001308	0.001345	0.002653	0.12%	0.12%	0.24%
9	1.102132	1.103244	1.104404	0.0011122	0.001159	0.002271	0.10%	0.11%	0.21%
10	1.084612	1.084935	1.085349	0.0003236	0.000414	0.000738	0.03%	0.04%	0.07%
HNI - Household net income									
1	12646.23	12634.93	12624.94	-11.2975	-9.98882	-21.2863	-0.09%	-0.08%	-0.17%
2	15980.43	15946.98	15917.39	-33.45238	-29.5802	-63.0326	-0.21%	-0.19%	-0.39%
3	21397.41	21335.63	21281.05	-61.78526	-54.578	-116.363	-0.29%	-0.26%	-0.54%
4	26924.95	26825.78	26738.01	-99.17542	-87.7658	-186.941	-0.37%	-0.33%	-0.69%
5	33964.3	33820.99	33693.75	-143.3024	-127.24	-270.543	-0.42%	-0.38%	-0.80%
6	41983.06	41785.13	41608.53	-197.9378	-176.592	-374.53	-0.47%	-0.42%	-0.89%
7	49606.74	49350.64	49121.64	-256.0982	-229.004	-485.102	-0.52%	-0.46%	-0.98%
8	59022.54	58692.35	58396.36	-330.1878	-295.994	-626.182	-0.56%	-0.50%	-1.06%
9	71663.94	71243.33	70865.84	-420.6106	-377.487	-798.097	-0.59%	-0.53%	-1.11%
10	121536.8	120800.6	120141.6	-736.2427	-658.989	-1395.23	-0.61%	-0.55%	-1.15%
QD - Output by sector									
Alcohol and Tobbacco	8040.931	8062.031	8085.576	21.099967	23.54488	44.64485	0.26%	0.29%	0.56%
Clothing	10013.42	9976.726	9945.308	-36.69796	-31.418	-68.1159	-0.37%	-0.31%	-0.68%
Durables	77388.45	77251.5	77130.72	-136.9462	-120.785	-257.731	-0.18%	-0.16%	-0.33%
Coal Extraction	3828.899	3828.618	3828.343	-0.28107	-0.27464	-0.55571	-0.01%	-0.01%	-0.01%
Oil and Gas Extraction	11812.04	11814.25	11816.45	2.2094898	2.197697	4.407187	0.02%	0.02%	0.04%
Coke, Oil Production	11088.18	11085.74	11083.36	-2.440009	-2.37884	-4.81885	-0.02%	-0.02%	-0.04%
Electricity	22105.06	22098.36	22091.78	-6.700598	-6.57632	-13.2769	-0.03%	-0.03%	-0.06%
Gas	6980.803	6975.544	6970.382	-5.259194	-5.16252	-10.4217	-0.08%	-0.07%	-0.15%
Food	56290.27	55861.13	55462.8	-429.1441	-398.328	-827.472	-0.76%	-0.71%	-1.47%
Government	79013.7	78964.74	78921.35	-48.96335	-43.3857	-92.3491	-0.06%	-0.05%	-0.12%
Household Durables	39382.91	39225.06	39084.01	-157.8511	-141.056	-298.907	-0.40%	-0.36%	-0.76%
Other	45684.03	45630.85	45584.29	-53.18289	-46.5652	-99.748	-0.12%	-0.10%	-0.22%
Construction Materials	103756.9	103562.8	103389.8	-194.0679	-173.069	-367.137	-0.19%	-0.17%	-0.35%
Services	173169	172862.4	172586.5	-306.5954	-275.887	-582.483	-0.18%	-0.16%	-0.34%
Business Services	48677.7	48654.49	48633.91	-23.21375	-20.5779	-43.7917	-0.05%	-0.04%	-0.09%
Transport	48410.3	48106.65	47829.84	-303.6491	-276.814	-580.463	-0.63%	-0.58%	-1.20%
Capital Goods	125209.2	124768.3	124377.9	-440.9304	-390.387	-831.317	-0.35%	-0.31%	-0.66%
Raw Materials	50931.23	50936.93	50942.73	5.703518	5.792265	11.49578	0.01%	0.01%	0.02%

Appendix: 5k Uncompensated wage elasticity sensitivity

Baseline (1): SE=0.4,(2) SE=0.1, Et=2x ,(3) SE=01, Et=3x (3)

	1	2	3	1 to 2	2 to 3	1 to 3	%1-2	%2-3	%1-3
w	0.909091	0.905744	0.902753	-0.003347	-0.00299	-0.00634	-0.37%	-0.33%	-0.70%
r	1	0.982423	0.96684	-0.017577	-0.01558	-0.03316	-1.76%	-1.59%	-3.32%
E	1	0.99699	0.993997	-0.00301	-0.00299	-0.006	-0.30%	-0.30%	-0.60%
Q	920591.2	919574.3	917586.7	-1016.916	-1987.6	-3004.52	-0.11%	-0.22%	-0.33%
Q P index	1	1.001951	1.003912	0.0019505	0.001961	0.003912	0.20%	0.20%	0.39%
Q P t index	1.05769	1.059684	1.067807	0.0019933	0.008124	0.010117	0.19%	0.77%	0.96%
C P Index	1.118159	1.117319	1.118877	-0.00084	0.001558	0.000718	-0.08%	0.14%	0.06%
Consumption	293033.3	291530.7	290073	-1502.6	-1457.76	-2960.36	-0.51%	-0.50%	-1.01%
Government Expenditure	104994.2	104994.2	104994.2	0	0	0	0.00%	0.00%	0.00%
Capital Expenditure	104196.2	103788.1	103204	-408.1034	-584.103	-992.207	-0.39%	-0.56%	-0.95%
Stocks	3294.541	3294.541	3294.541	0	0	0	0.00%	0.00%	0.00%
Exports	128085	128626.7	128667	541.76455	40.32546	582.09	0.42%	0.03%	0.45%
Imports - Final Demand	143660.9	143308.9	143294.9	-352.0233	-13.9349	-365.958	-0.25%	-0.01%	-0.25%
G expenditure (£)	278138.2	278057.5	278239.6	-80.7596	182.135	101.3754	-0.03%	0.07%	0.04%
G revenue £	270580	269754.4	279787	-825.641	10032.66	9207.02	-0.31%	3.72%	3.40%
T L D - Total labour supply	310675.4	310249.6	310021.3	-425.794	-228.249	-654.043	-0.14%	-0.07%	-0.21%
HLD - Household labour supply									
1	207.2714	207.2824	207.556	0.0110481	0.27352	0.284568	0.01%	0.13%	0.14%
2	640.8258	641.4653	642.834	0.6394653	1.368676	2.008141	0.10%	0.21%	0.31%
3	3473.603	3478.838	3486.98	5.2350167	8.141941	13.37696	0.15%	0.23%	0.39%
4	10353.38	10368.15	10386.48	14.77051	18.32894	33.09945	0.14%	0.18%	0.32%
5	18552.93	18572.11	18590.95	19.172925	18.84419	38.01711	0.10%	0.10%	0.20%
6	28967.62	28977.59	28976.12	9.9696311	-1.46402	8.505615	0.03%	-0.01%	0.03%
7	37629.86	37632.36	37611.74	2.5074535	-20.628	-18.1206	0.01%	-0.05%	-0.05%
8	48256.19	48240.11	48182.66	-16.08496	-57.4508	-73.5358	-0.03%	-0.12%	-0.15%
9	61208.19	61175.67	61082.02	-32.52068	-93.6502	-126.171	-0.05%	-0.15%	-0.21%
10	100959.7	100956	100854	-3.700406	-102.014	-105.714	0.00%	-0.10%	-0.10%
HP - Consumption price index									
1	1.16323	1.163026	1.165411	-0.000204	0.002385	0.002181	-0.02%	0.21%	0.19%
2	1.161043	1.16084	1.163301	-0.000203	0.002461	0.002258	-0.02%	0.21%	0.19%
3	1.151027	1.150825	1.15336	-0.000202	0.002534	0.002332	-0.02%	0.22%	0.20%
4	1.145478	1.145137	1.147524	-0.000342	0.002388	0.002046	-0.03%	0.21%	0.18%
5	1.140481	1.140046	1.142346	-0.000435	0.0023	0.001865	-0.04%	0.20%	0.16%
6	1.128049	1.127483	1.129535	-0.000566	0.002052	0.001486	-0.05%	0.18%	0.13%
7	1.118987	1.118174	1.119833	-0.000813	0.00166	0.000847	-0.07%	0.15%	0.08%
8	1.109133	1.108116	1.109432	-0.001017	0.001316	0.000299	-0.09%	0.12%	0.03%
9	1.102992	1.101866	1.102994	-0.001125	0.001128	2.34E-06	-0.10%	0.10%	0.00%
10	1.08489	1.083293	1.083662	-0.001598	0.000369	-0.00123	-0.15%	0.03%	-0.11%
HNI - Household net income									
1	12646.45	12634.61	12624.33	-11.8426	-10.2837	-22.1263	-0.09%	-0.08%	-0.17%
2	15981.12	15946.04	15915.58	-35.08417	-30.454	-65.5382	-0.22%	-0.19%	-0.41%
3	21400.21	21333.84	21277.6	-66.36932	-56.2407	-122.61	-0.31%	-0.26%	-0.57%
4	26928.92	26822.89	26732.45	-106.0295	-90.4398	-196.469	-0.39%	-0.34%	-0.73%
5	33965.68	33816.92	33685.92	-148.7595	-131.006	-279.766	-0.44%	-0.39%	-0.82%
6	41975.72	41779.74	41598.16	-195.982	-181.573	-377.555	-0.47%	-0.43%	-0.90%
7	49590.59	49343.86	49108.58	-246.7282	-235.284	-482.012	-0.50%	-0.48%	-0.97%
8	58992.27	58683.89	58380.04	-308.3813	-303.848	-612.229	-0.52%	-0.52%	-1.04%
9	71619.34	71232.75	70845.42	-386.5903	-387.329	-773.919	-0.54%	-0.54%	-1.08%
10	121470.5	120781.9	120105.5	-688.616	-676.391	-1365.01	-0.57%	-0.56%	-1.12%
QD - Output by sector									
Alcohol and Tobbacco	8080.841	8061.814	8090.175	-19.02672	28.36112	9.334407	-0.24%	0.35%	0.12%
Clothing	9996.051	9983.921	9959.417	-12.13015	-24.5038	-36.634	-0.12%	-0.25%	-0.37%
Durables	77098.18	77172.93	76978.48	74.757042	-194.45	-119.693	0.10%	-0.25%	-0.16%
Coal Extraction	3826.53	3828.657	3828.378	2.1269022	-0.27857	1.848328	0.06%	-0.01%	0.05%
Oil and Gas Extraction	11779.49	11814.25	11816.45	34.758335	2.197697	36.95603	0.30%	0.02%	0.31%
Coke, Oil Production	11065.44	11086.12	11083.7	20.679568	-2.41662	18.26295	0.19%	-0.02%	0.17%
Electricity	22097.23	22099.05	22092.4	1.8103447	-6.6456	-4.83526	0.01%	-0.03%	-0.02%
Gas	6975.758	6976.077	6970.861	0.3189876	-5.21621	-4.89722	0.00%	-0.07%	-0.07%
Food	56061.19	55891.68	55521.59	-169.5083	-370.097	-539.605	-0.30%	-0.66%	-0.96%
Government	79016.89	78971.98	78935.42	-44.90943	-36.5647	-81.4741	-0.06%	-0.05%	-0.10%
Household Durables	39374.3	39245.86	39124.35	-128.4424	-121.508	-249.95	-0.33%	-0.31%	-0.63%
Other	45610.68	45639.43	45600.94	28.74827	-38.49	-9.74169	0.06%	-0.08%	-0.02%
Construction Materials	103623.5	103402.8	103079.6	-220.7186	-323.168	-543.886	-0.21%	-0.31%	-0.52%
Services	173080.5	172900.2	172659.8	-180.301	-240.46	-420.761	-0.10%	-0.14%	-0.24%
Business Services	48639.06	48635.08	48596.3	-3.979758	-38.78	-42.7597	-0.01%	-0.08%	-0.09%
Transport	48293.26	48138.72	47888.24	-154.537	-250.478	-405.015	-0.32%	-0.52%	-0.84%
Capital Goods	125150.9	124788.6	124417.6	-362.2344	-371.054	-733.289	-0.29%	-0.30%	-0.59%
Raw Materials	50821.43	50937.1	50943.05	115.67289	5.947767	121.6207	0.23%	0.01%	0.24%

Chapter 6 - Results of the general equilibrium model

After the explanation of the theoretical background to the general equilibrium model in chapter 4 and the description of the data used and the calibration processes under taken in chapter 5, this chapter presents a comprehensive selection of general equilibrium results.

The focus in this chapter is on revenue-neutral changes in the tax mix[1]. Namely, the tax rate on energy is increased (either on energy consumption or the producer tax on the energy production sectors) and this additional revenue is returned by lowering other tax rates. Government spending remains fixed in terms of the quantity of goods purchased, but will vary in terms of money expenditure as prices in the model adjust to equilibrium. revenue neutrality implies that the government's budget position is left unchanged after the rise in the energy tax and the reduction in the other form of tax.

The structure of the model allows the revenue returning instrument to be any of the following:

- General consumption taxes
- Producer taxes on labour inputs
- Corporation (capital) taxation
- Income taxation
- Lump-sum transfer

The effect of different forms of energy taxes in the context of each of the above potential revenue returning instruments are analysed. In each case, the rates of energy taxation are varied in two ways. Firstly, the initial tax rate on each energy good is doubled, and secondly, it is tripled. This second instance is somewhat extreme but does give an indication of the levels of tax increases required to reduce energy use by a significant amount.

Section 6.1 considers the imposition of a consumption tax - producers pay no more for energy as an input but households pay more for the consumption good, Fuel. This section may be compared relatively directly, when the revenue recycling instrument in consumption taxation, with the results for the marginal cost of funds (under revenue neutrality) presented in chapter 3. Section 6.2 considers a tax on energy at the producer level - the price that producers must pay for energy increases. This increase in the cost of a factor of production will cause substitute between energy and the other (direct) inputs to the production process, namely Labour and Capital.

As detailed above, in each section, the level of the revenue-returning instrument is adjusted so that the government's budget position is the same as in the baseline case - a deficit of 18102. This adjustment takes the form of a tax cut in all cases except lump-sum transfers when the level of transfers are increased. These changes in lump-sum transfers are made at a proportionally equal level for all households.

6.1 Consumer energy taxes

In this section the two energy tax scenarios considered are a doubling and a tripling of the existing tax on the consumer energy good, FUEL. For each tax change the five possible revenue recycling methods - consumption taxes (excluding energy), producer taxes on labour, corporation tax (a tax on the return to capital), income tax and lump-sum transfers are analysed.

The effect of the two energy tax change scenarios on the levels of the FUEL tax are shown in Table 6.1.

Table 6.1 - Level of FUEL taxes under the two scenarios

	Level of FUEL tax		
	Baseline	Scenario 1 FUEL tax doubled	Scenario 2 FUEL tax tripled
FUEL tax	0.149	0.298	0.447

The full set of results for this section can be found in appendix 6a and 6b. The required levels of changes in each of the five revenue recycling instruments for an equilibrium in the model under the two scenarios are given in Table 6.2.

Table 6.2 - Change in revenue instrument required for equilibrium.

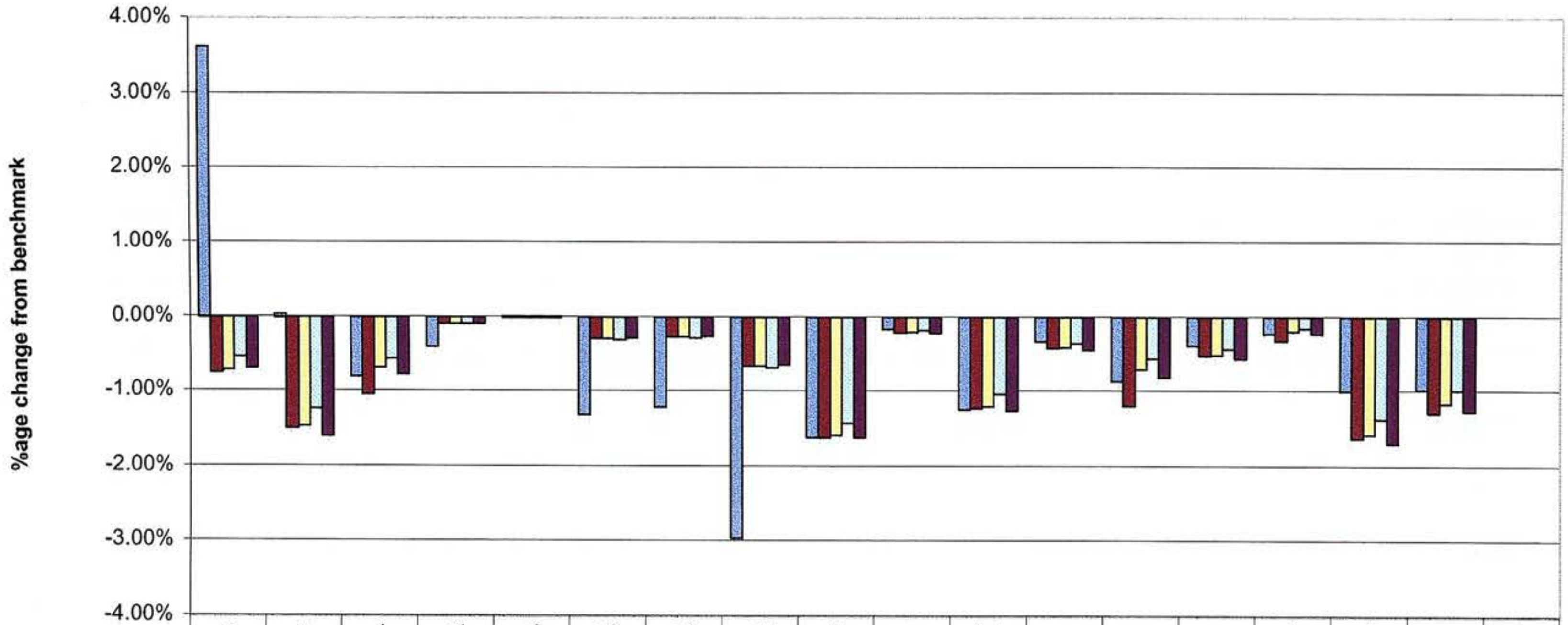
	Change in revenue recycling instrument.		
	Baseline	Scenario 1 FUEL tax doubled	Scenario 2 FUEL tax tripled
Consumption tax - %age change in all consumer taxation except Fuel	-	-5.78	-11.55
Producer labour taxes - level	0.1	0.14	0.18
Corporation tax - level	0.4	0.37	0.35
Income tax - %age change in rate faced by each household	-	-3.31	-6.15
Lump-sum transfer - %age change	-	1.38	2.65

Given the two scenarios and 5 recycling instruments there are 10 'runs' of the model presented in this section[2]. The results are divided into two sub-sections. Section 6.1.1 deals with what are termed efficiency effects. This is the overall impact of the tax reform on the economy as a whole, in terms of macro-economic variables and production sector output. Section 6.1.2 examines the impact of each run of the model at a household level

6.1.1 Efficiency effects

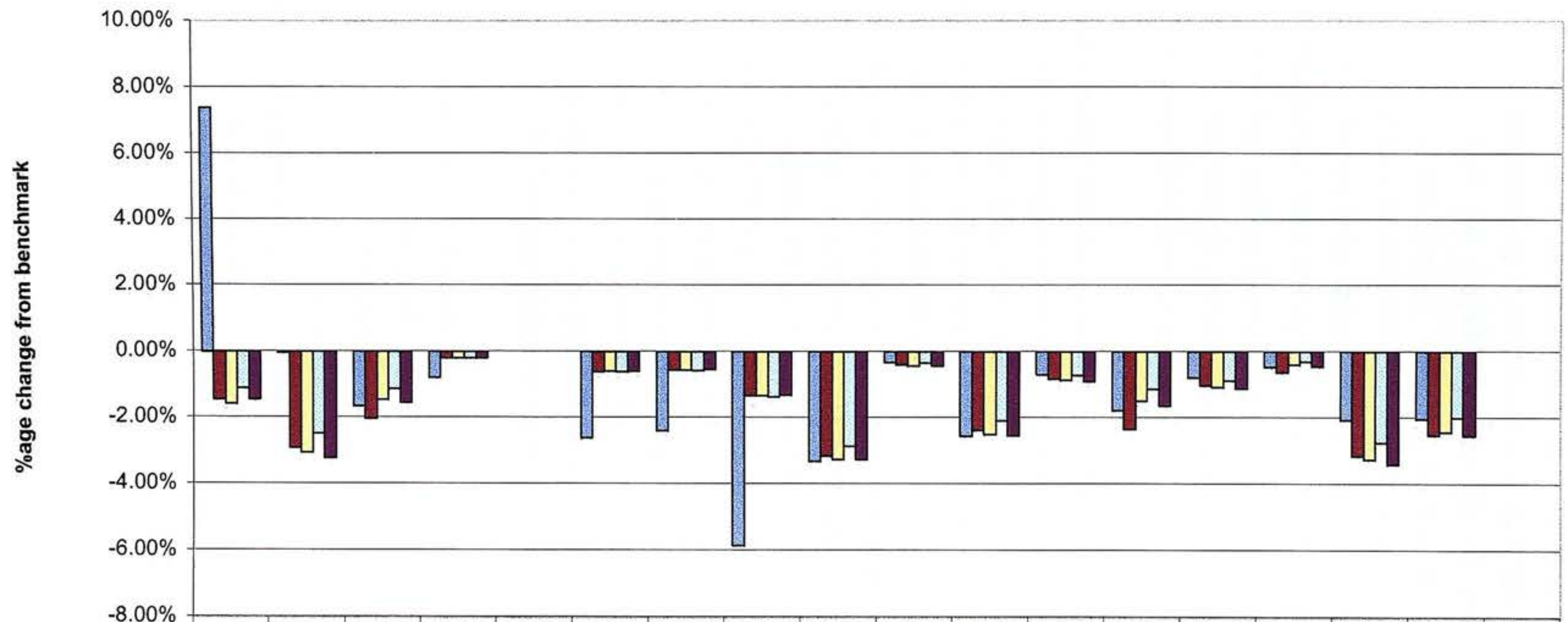
The change in the output of each of the production sectors under the two scenarios and five revenue recycling instruments is shown in Figure 6.1 (a and b respectively for the two scenarios). This figure will be returned to subsequently but initially just the effect on the energy producing sectors is considered. It is, after all, a reduction in energy usage (or production) that is primary aim of the tax reform being considered.

Figure 6.1a - Output changes with doubling of consumption tax



	a	c	d	e1	e2	e3	e4	e5	f	g	hd	o	oc	s	sb	t	z	zm
C taxes	3.62%	0.03%	-0.80%	-0.40%	0.00%	-1.31%	-1.21%	-2.96%	-1.61%	-0.16%	-1.23%	-0.32%	-0.86%	-0.38%	-0.22%	-0.99%	-0.98%	-0.01%
P Labour	-0.75%	-1.49%	-1.04%	-0.09%	0.00%	-0.29%	-0.27%	-0.65%	-1.61%	-0.20%	-1.22%	-0.42%	-1.19%	-0.52%	-0.31%	-1.62%	-1.28%	-0.01%
Corporation	-0.71%	-1.46%	-0.68%	-0.09%	0.00%	-0.29%	-0.27%	-0.65%	-1.58%	-0.20%	-1.19%	-0.41%	-0.70%	-0.51%	-0.19%	-1.57%	-1.16%	-0.01%
Income	-0.53%	-1.23%	-0.56%	-0.09%	0.00%	-0.30%	-0.28%	-0.68%	-1.42%	-0.17%	-1.03%	-0.35%	-0.56%	-0.43%	-0.15%	-1.37%	-0.98%	-0.01%
Lump-sum	-0.69%	-1.60%	-0.77%	-0.09%	0.00%	-0.28%	-0.26%	-0.64%	-1.62%	-0.21%	-1.26%	-0.44%	-0.81%	-0.55%	-0.22%	-1.70%	-1.26%	-0.01%

Figure 6.1 b - Output changes with a tripling of the consumption energy tax



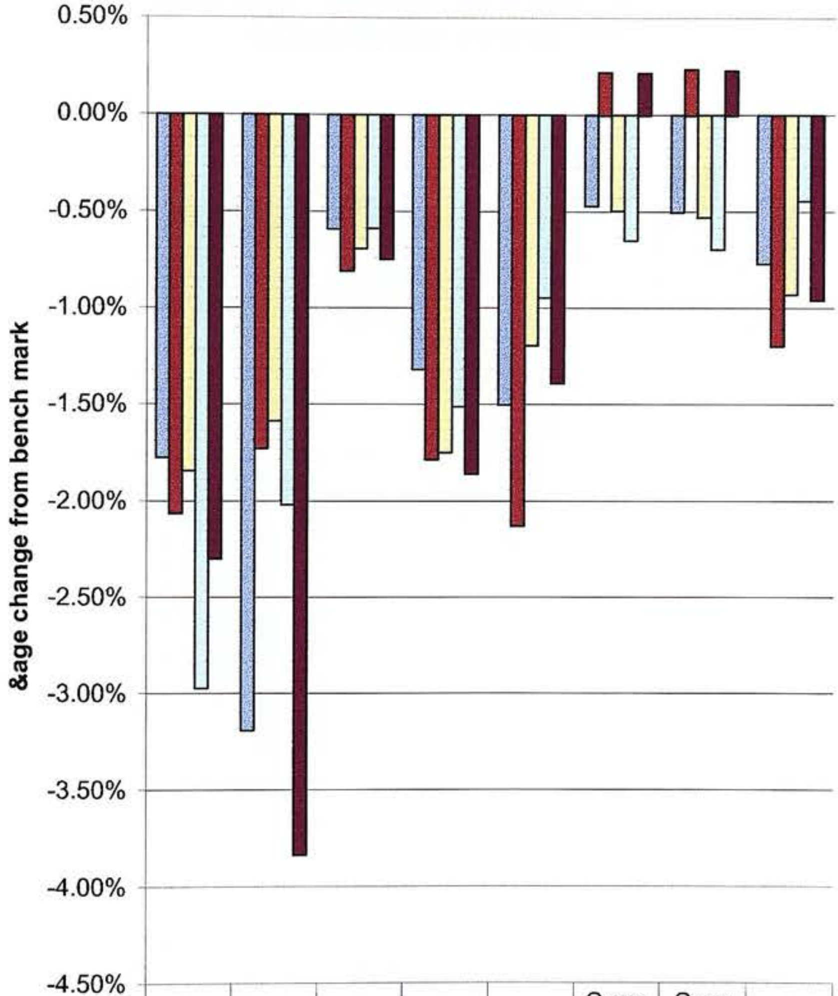
	a	c	d	e1	e2	e3	e4	e5	f	g	hd	o	oc	s	sb	t	z	zm
C taxes	7.40%	-0.02%	-1.64%	-0.78%	0.00%	-2.59%	-2.38%	-5.84%	-3.30%	-0.33%	-2.53%	-0.67%	-1.76%	-0.79%	-0.46%	-2.05%	-2.02%	-0.01%
P Labour	-1.44%	-2.89%	-2.02%	-0.18%	0.00%	-0.59%	-0.54%	-1.32%	-3.15%	-0.40%	-2.38%	-0.81%	-2.33%	-1.01%	-0.62%	-3.14%	-2.50%	-0.01%
Corporation	-1.57%	-3.05%	-1.43%	-0.18%	0.00%	-0.58%	-0.53%	-1.31%	-3.25%	-0.41%	-2.48%	-0.85%	-1.48%	-1.05%	-0.39%	-3.24%	-2.43%	-0.01%
Income	-1.11%	-2.48%	-1.13%	-0.18%	0.00%	-0.60%	-0.55%	-1.36%	-2.85%	-0.34%	-2.08%	-0.71%	-1.13%	-0.87%	-0.30%	-2.75%	-1.99%	-0.01%
Lump-sum	-1.44%	-3.20%	-1.54%	-0.17%	0.00%	-0.57%	-0.53%	-1.29%	-3.24%	-0.43%	-2.52%	-0.88%	-1.62%	-1.11%	-0.43%	-3.39%	-2.53%	-0.02%

It is worth, at this stage, recalling the exact nature of the five energy producing sectors. E1 is coal extraction, e2 is oil and gas extraction, e3 is coke and oil production, e4 is electricity and e5 is gas. An examination of figure 6.1 shows that the output of sector e2, oil and gas extraction is unaffected in any of the 10 runs. Referring back to the domestic use matrix in appendix 5a, it may be seen that the output of sector e2 is primarily used as an input to sector e3, coke and oil production, and to a lesser extent sector e5 (gas production). It does not appear in the FUEL consumption composite at all. There is thus only an indirect effect on this sector through changes in demand for the two energy goods for which it is a primary input and this indirect effect appears to be negligible.

All the other energy sectors experience a reduction in output. The effect is generally speaking double when the consumption energy tax is tripled as opposed to doubled. However, the overall effect is relatively small (in percentage terms) for all sectors except e5, gas. The highest percentage change for each run occurs for sector e5, sectors e3 and e4 face broadly even percentage changes in each run and sector e1 faces the smallest percentage change. This is perhaps surprising in that, although sector e1 makes up only 2.4% of the FUEL composite, sector e4 accounts for 42.1% whilst sectors e3 and e5 account for 22.9% and 32.6% of the FUEL composite. It would be thus expected that it would be sector e4 that is most affected. Examining the model data in terms of absolute rather than percentage changes shows that it is indeed sector e4 that experiences the highest absolute fall in output. Indeed, the magnitude of the relative absolute effect on each sector is broadly in line with the share of that sector in the consumption composite.

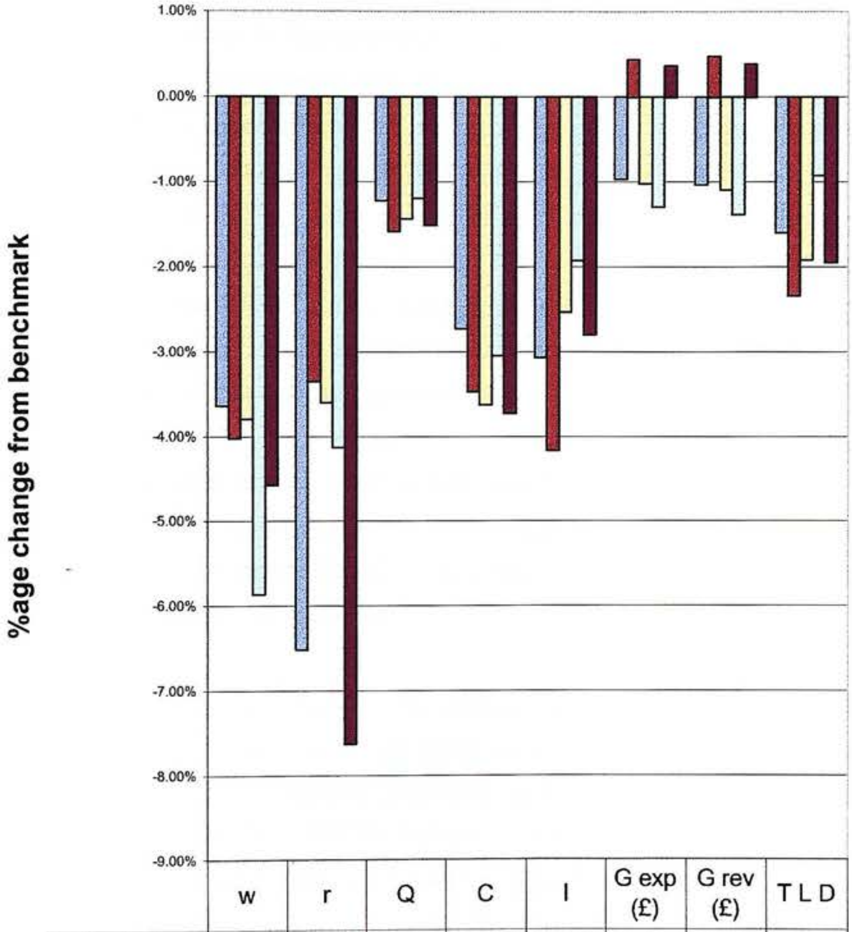
What is also noticeable is that the extent of the effect on the output of the energy sectors varies considerably with the recycling instrument chosen. The change is the supply of energy is greatest with consumption taxes, and lowest with producer labour taxes as the revenue recycling instrument. Corporation and income taxes and lump-sum transfers have broadly the same effect which is of an order of magnitude of around a quarter that of consumption taxes.

Figure 6.2a - Results for a doubling of Consumption energy tax



	w	r	Q	C	I	G exp (£)	G rev (£)	T L D
C taxes	-1.77%	-3.19%	-0.59%	-1.32%	-1.50%	-0.47%	-0.50%	-0.77%
P Labour	-2.06%	-1.73%	-0.81%	-1.78%	-2.13%	0.22%	0.23%	-1.20%
Corporation	-1.84%	-1.58%	-0.69%	-1.75%	-1.19%	-0.50%	-0.53%	-0.93%
Income	-2.97%	-2.02%	-0.59%	-1.51%	-0.94%	-0.65%	-0.69%	-0.44%
Lump-sum	-2.30%	-3.83%	-0.75%	-1.86%	-1.39%	0.21%	0.23%	-0.96%

Figure 6.2b - Results for a tripling of consumption energy tax



	w	r	Q	C	I	G exp (£)	G rev (£)	T L D
C taxes	-3.64%	-6.51%	-1.21%	-2.72%	-3.06%	-0.96%	-1.03%	-1.60%
P Labour	-4.02%	-3.35%	-1.57%	-3.46%	-4.16%	0.44%	0.47%	-2.34%
Corporation	-3.79%	-3.60%	-1.44%	-3.62%	-2.53%	-1.01%	-1.09%	-1.91%
Income	-5.87%	-4.12%	-1.18%	-3.04%	-1.92%	-1.29%	-1.38%	-0.91%
Lump-sum	-4.57%	-7.62%	-1.50%	-3.73%	-2.80%	0.36%	0.38%	-1.95%

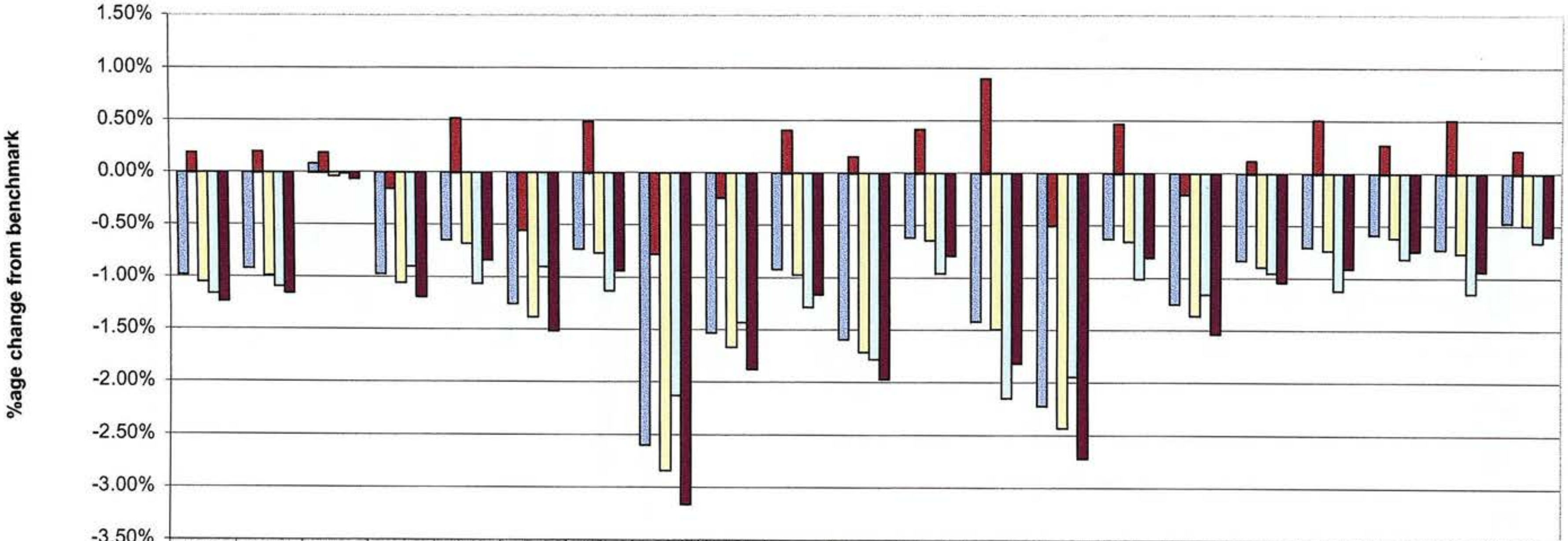
Figure 6.2 (a and b) presents changes in other selected variables. The wage level and the interest rate fall in both scenarios and again the effect is approximately twice as strong when the energy tax rate is tripled as opposed to doubled. The return to capital falls most when lump-sum transfers are used for recycling. There is only a negligible effect on the exchange rate in all instances. See Appendices.

Output also falls in all cases. The fall in output is greatest when the producer labour tax is the revenue returning instrument and lowest when it is income tax[3]. Lump-sum transfers are inferior to all means of recycling except producer labour taxes in terms of output. Thus, the weak form of the double dividend holds (provided the recycling instrument is not the producer labour tax). This result is in line with the existing empirical literature discussed in chapter 1 with the exception of Brinner et. al. (1992) who find that producer labour taxes are the most suitable instrument. Given that they consider a producer based energy tax it is unfair to make a comparison until the following section[4].

Consumption falls in all runs of the model and unsurprisingly the fall is least when consumption taxes are used as the recycling instrument. Investment, on the other hand, falls least when income tax is used for the return of the energy tax revenue.

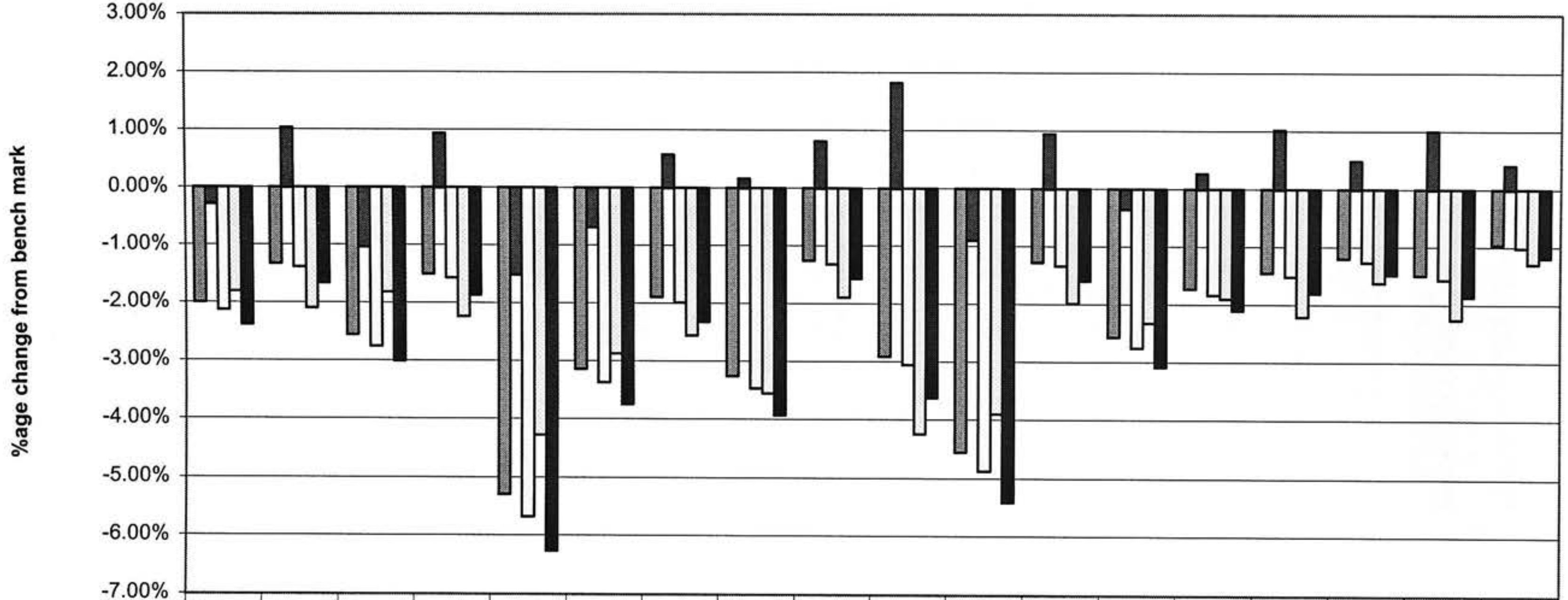
Figure 6.3 (a and b) shows the effect on producer prices. The overall producer price index falls in all runs except those where producer labour taxes are adjusted and indeed it is only in this case that any of the producer prices rise. The greatest fall in producer price is faced by the e_2 sector and this ties in nicely with the fact raised above that the output of this sector is not affected by the energy tax rise. Remembering that sector e_2 is not a component of composite energy consumption it is clear that this sector, which primarily supplies other energy sectors, accepts a lower price for it output when demand falls due to the fall in other energy type use. The overall impact on producer prices is highest with lump-sum transfers although there is some variation across sectors.

Figure 6.3a - Changes in producer prices - doubling of consumption energy tax



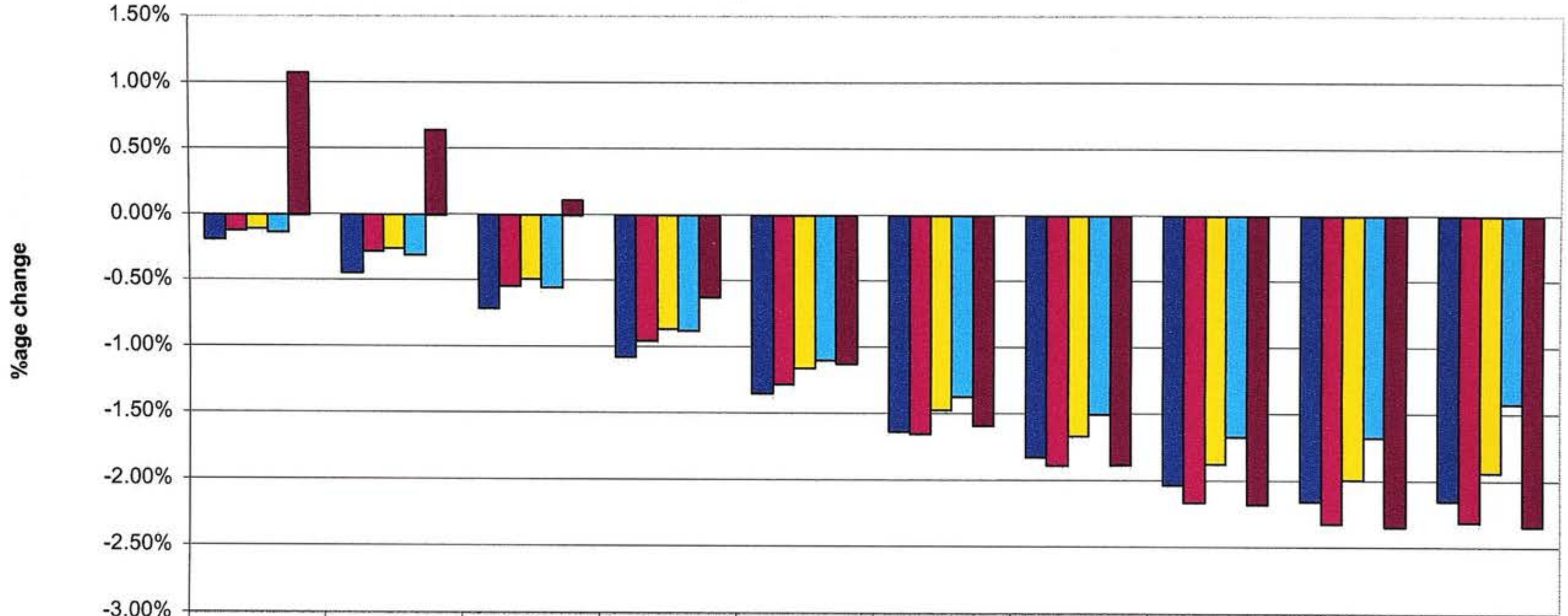
	Q P index	Q P t index	C P Index	a	c	d	e1	e2	e3	e4	e5	f	g	hd	o	oc	s	sb	t	z	zm
C taxes	-0.98%	-0.91%	0.08%	-0.97%	-0.64%	-1.25%	-0.73%	-2.59%	-1.53%	-0.91%	-1.58%	-0.61%	-1.41%	-2.22%	-0.62%	-1.25%	-0.83%	-0.70%	-0.58%	-0.72%	-0.46%
P Labour	0.19%	0.20%	0.19%	-0.15%	0.52%	-0.55%	0.49%	-0.77%	-0.23%	0.41%	0.16%	0.42%	0.90%	-0.49%	0.48%	-0.19%	0.12%	0.51%	0.28%	0.51%	0.22%
Corporation	-1.05%	-0.98%	-0.03%	-1.05%	-0.67%	-1.38%	-0.76%	-2.83%	-1.66%	-0.97%	-1.70%	-0.64%	-1.48%	-2.42%	-0.65%	-1.36%	-0.89%	-0.73%	-0.61%	-0.76%	-0.49%
Income	-1.16%	-1.09%	0.00%	-0.89%	-1.06%	-0.89%	-1.13%	-2.12%	-1.42%	-1.28%	-1.77%	-0.95%	-2.14%	-1.94%	-1.00%	-1.15%	-0.95%	-1.11%	-0.81%	-1.14%	-0.65%
Lump-sum	-1.23%	-1.15%	-0.06%	-1.19%	-0.83%	-1.51%	-0.93%	-3.15%	-1.87%	-1.16%	-1.97%	-0.78%	-1.81%	-2.71%	-0.80%	-1.53%	-1.03%	-0.90%	-0.74%	-0.93%	-0.59%

Figure 6.3b - Changes in producer prices - tripling of consumption energy tax



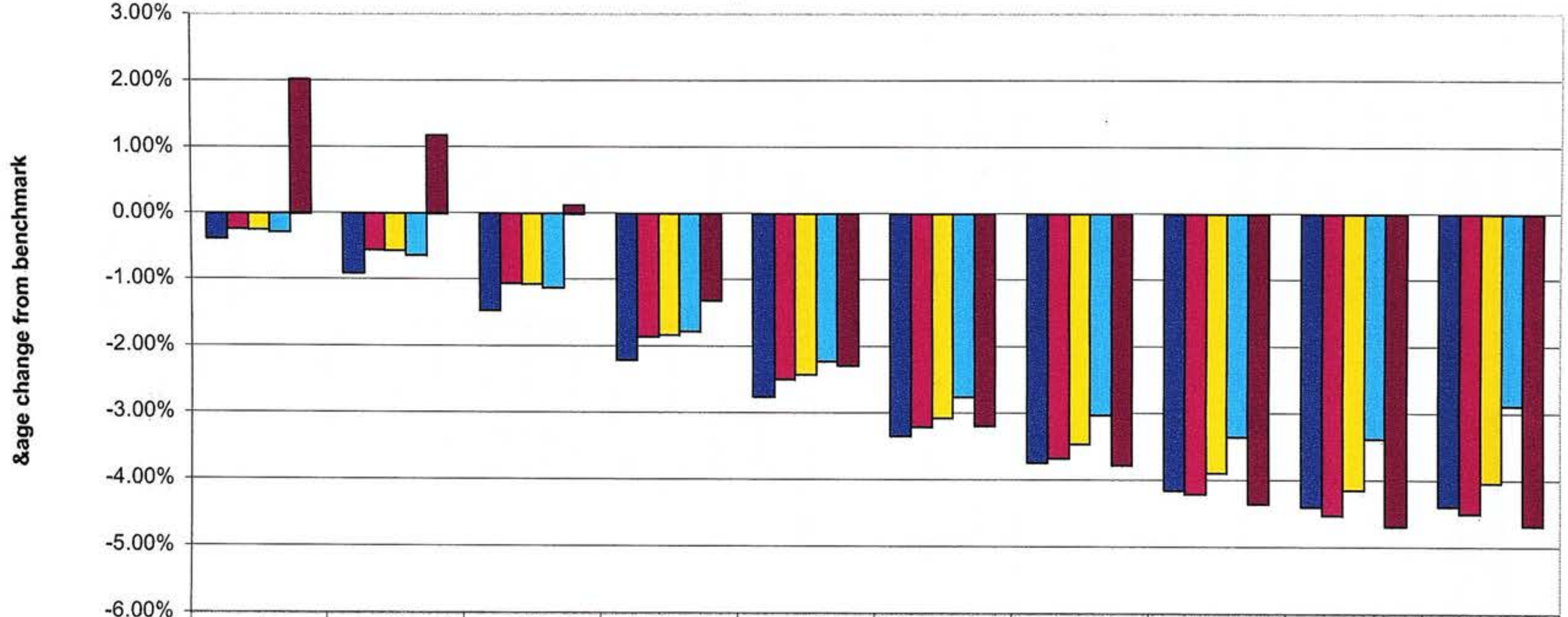
	a	c	d	e1	e2	e3	e4	e5	f	g	hd	o	oc	s	sb	t	z	zm
C tax	-1.99%	-1.32%	-2.55%	-1.49%	-5.29%	-3.13%	-1.88%	-3.25%	-1.25%	-2.90%	-4.54%	-1.27%	-2.57%	-1.72%	-1.44%	-1.20%	-1.49%	-0.96%
P labour	-0.29%	1.04%	-1.03%	0.94%	-1.51%	-0.69%	0.57%	0.16%	0.81%	1.83%	-0.90%	0.94%	-0.35%	0.26%	1.03%	0.49%	1.01%	0.40%
Corporation	-2.13%	-1.38%	-2.74%	-1.56%	-5.68%	-3.36%	-1.98%	-3.45%	-1.31%	-3.05%	-4.87%	-1.33%	-2.75%	-1.83%	-1.51%	-1.26%	-1.56%	-1.01%
Income	-1.80%	-2.09%	-1.80%	-2.23%	-4.27%	-2.86%	-2.54%	-3.54%	-1.89%	-4.24%	-3.90%	-1.98%	-2.31%	-1.90%	-2.20%	-1.61%	-2.25%	-1.29%
Lump-sum	-2.38%	-1.65%	-3.00%	-1.86%	-6.26%	-3.74%	-2.32%	-3.92%	-1.56%	-3.61%	-5.41%	-1.59%	-3.08%	-2.09%	-1.80%	-1.47%	-1.85%	-1.18%

Figure 6.4a - Change in household income - consumption energy tax doubled



	1	2	3	4	5	6	7	8	9	10
C taxes	-0.19%	-0.44%	-0.71%	-1.07%	-1.34%	-1.63%	-1.82%	-2.03%	-2.15%	-2.14%
P Labour	-0.12%	-0.28%	-0.54%	-0.95%	-1.28%	-1.65%	-1.88%	-2.16%	-2.32%	-2.30%
Corporation	-0.11%	-0.25%	-0.49%	-0.86%	-1.15%	-1.47%	-1.66%	-1.87%	-1.99%	-1.93%
Income	-0.13%	-0.31%	-0.55%	-0.88%	-1.10%	-1.37%	-1.50%	-1.66%	-1.67%	-1.42%
Lump-sum	1.07%	0.64%	0.11%	-0.62%	-1.12%	-1.59%	-1.88%	-2.17%	-2.34%	-2.33%

Figure 6.4b - Changes in household income - consumption energy tax tripled



	1	2	3	4	5	6	7	8	9	10
C taxes	-0.38%	-0.89%	-1.45%	-2.20%	-2.75%	-3.33%	-3.72%	-4.14%	-4.39%	-4.38%
P Labour	-0.23%	-0.54%	-1.05%	-1.85%	-2.49%	-3.20%	-3.67%	-4.20%	-4.51%	-4.48%
Corporation	-0.24%	-0.56%	-1.06%	-1.82%	-2.42%	-3.06%	-3.45%	-3.88%	-4.13%	-4.02%
Income	-0.27%	-0.62%	-1.11%	-1.77%	-2.22%	-2.75%	-3.02%	-3.35%	-3.38%	-2.88%
Lump-sum	2.03%	1.18%	0.13%	-1.30%	-2.28%	-3.19%	-3.77%	-4.34%	-4.67%	-4.66%

The intuitive idea that revenue neutral tax reform is regressive arose from the fact that lower income households spend proportionately more of their income on energy. This reasoning is reinforced by the fact that under all revenue recycling instruments, broadly speaking, lower income household reduce their energy consumption proportionately more. However, this consumption effect is outweighed by the income effect explained above and the overall impact of the tax reform is progressive. This finding serves to illustrate the importance of applied empirical analysis.

6.2 Producer energy taxes

The analysis of the previous section is now repeated for a change in the producer tax rates on energy. The effect of the two energy tax change scenarios on the levels of the five producer energy taxes are shown in Table 6.3.

Table 6.3 - Level of producer energy taxes under the three scenarios

	Level of producer energy tax		
	Baseline	Scenario 1 Producer energy taxes doubled	Scenario 2 Producer energy taxes tripled
e1	-11.7%	0	11.7%
e2	4.5%	8.9%	13.4%
e3	10.0%	20.1%	30.2%
e4	12.1%	24.2%	36.3%
e5	18.5%	37.0%	55.6%

It will be noted that sector e_1 is initially receiving a subsidy. The changes in the tax rate are imposed in such a way that the doubling of the tax rate is equivalent to removal of the subsidy and the tripling of the tax rate is equivalent to a tax rate equal to the initial subsidy rate.

The full set of results for this section can be found in appendix 6c and 6d. The required levels of changes in each of the five revenue recycling instruments for an equilibrium in the model under the two scenarios are given in Table 6.4.

Table 6.4 - Change in revenue instrument required for equilibrium.

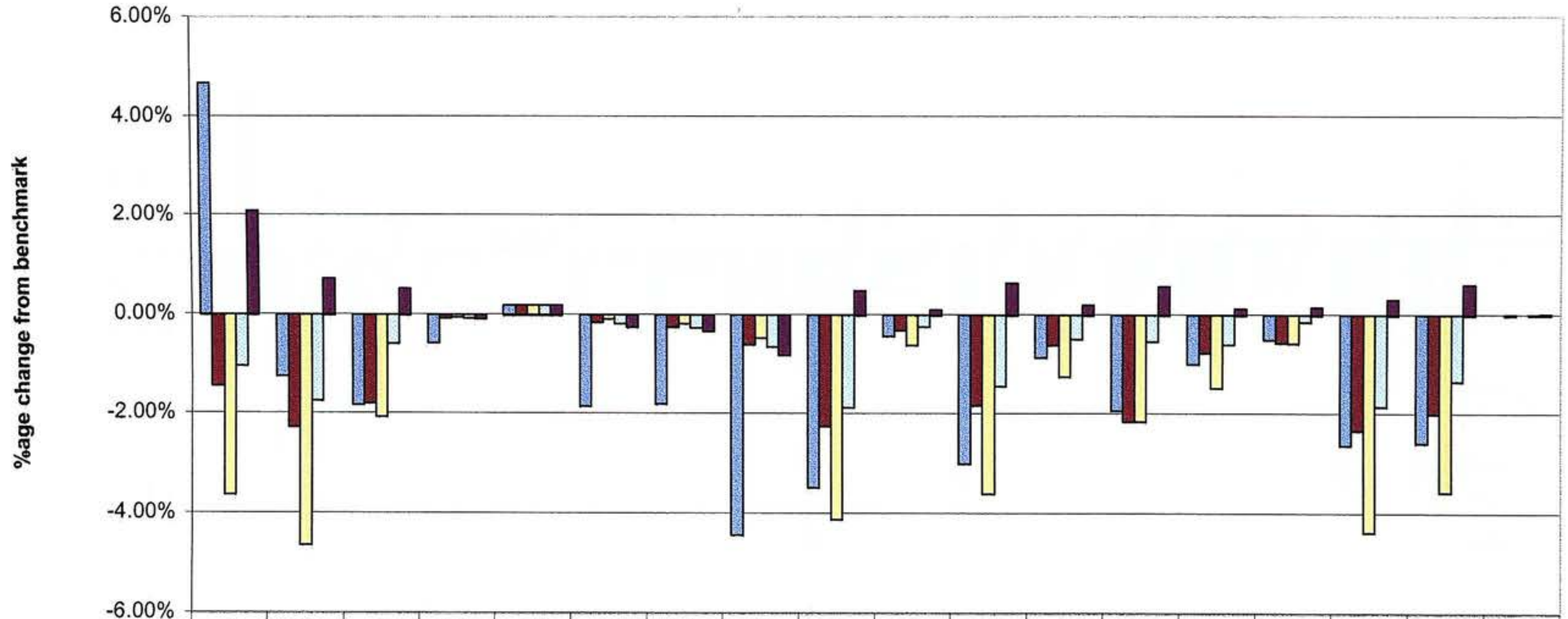
	Change in revenue recycling instrument.		
	Baseline	Scenario 1 FUEL tax doubled	Scenario 2 FUEL tax tripled
Consumption tax - %age change in all consumer taxation except Fuel	-	-6.28	-15.06
Producer labour taxes - level	0.1	0.21	0.33
Corporation tax - level	0.4	0.37	0.35
Income tax - %age change in rate faced by each household	-	-8.23	-16.93
Lump-sum transfer - %age change	-	7.19	14.7

Two issues are raised by Table 6.4. Firstly the changes in the revenue recycling instruments required for revenue neutrality under the producer tax reform are much higher than those under the consumer tax reform. Secondly, that a **rise** in the producer labour tax level is required[5]. This is somewhat counterintuitive and must be due to labour supply effects. Hence, although results for this recycling instrument are reported they are not included in analysis.

6.2.1 *Efficiency effects*

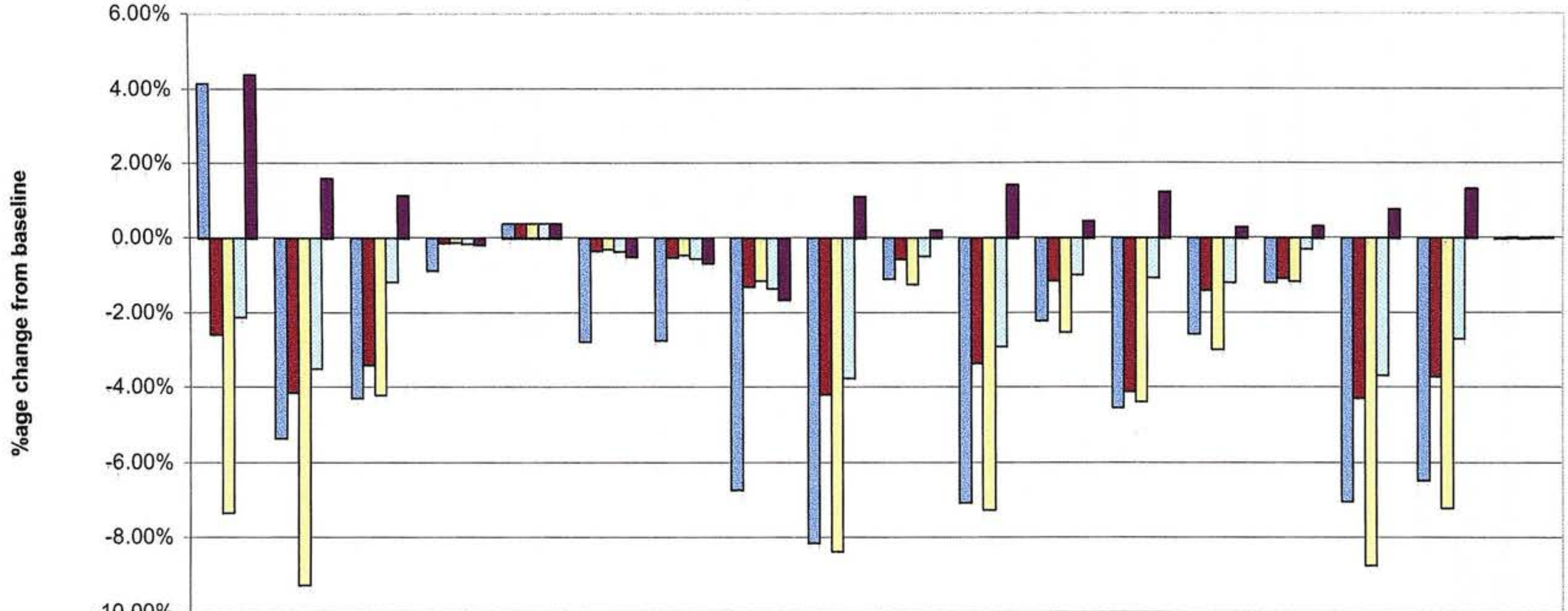
The change in the output of each of the production sectors under the two scenarios and five revenue recycling instruments is shown in Figure 6.5 (a and b respectively for the two scenarios). Again, initially just the effect on the energy producing sectors is considered.

Figure 6.5 a - Changes in output with a doubling of the producer energy tax rates



	a	c	d	e1	e2	e3	e4	e5	f	g	hd	o	oc	s	sb	t	z	zm
C taxes	4.67%	-1.25%	-1.82%	-0.57%	0.19%	-1.85%	-1.80%	-4.43%	-3.47%	-0.43%	-3.00%	-0.87%	-1.94%	-1.00%	-0.50%	-2.63%	-2.58%	0.00%
P Labour	-1.45%	-2.26%	-1.78%	-0.06%	0.19%	-0.16%	-0.24%	-0.61%	-2.24%	-0.31%	-1.82%	-0.62%	-2.14%	-0.76%	-0.56%	-2.33%	-1.99%	0.00%
Corporation	-3.62%	-4.63%	-2.06%	-0.04%	0.19%	-0.09%	-0.18%	-0.46%	-4.12%	-0.61%	-3.60%	-1.25%	-2.14%	-1.48%	-0.57%	-4.37%	-3.57%	-0.01%
Income	-1.04%	-1.74%	-0.58%	-0.06%	0.19%	-0.18%	-0.26%	-0.65%	-1.87%	-0.24%	-1.45%	-0.48%	-0.53%	-0.59%	-0.14%	-1.84%	-1.34%	0.00%
Lump-sum	2.10%	0.71%	0.52%	-0.09%	0.19%	-0.25%	-0.33%	-0.81%	0.49%	0.09%	0.64%	0.20%	0.57%	0.12%	0.15%	0.31%	0.60%	0.02%

Figure 6.5 b - Changes in output with a tripling of producer energy taxes



	a	c	d	e1	e2	e3	e4	e5	f	g	hd	o	oc	s	sb	t	z	zm
C taxes	4.15%	-5.35%	-4.27%	-0.85%	0.38%	-2.75%	-2.73%	-6.73%	-8.13%	-1.08%	-7.07%	-2.21%	-4.53%	-2.55%	-1.18%	-7.01%	-6.47%	-0.01%
P Labour	-2.57%	-4.12%	-3.38%	-0.13%	0.38%	-0.34%	-0.51%	-1.28%	-4.16%	-0.56%	-3.33%	-1.13%	-4.08%	-1.39%	-1.07%	-4.28%	-3.69%	0.01%
Corporation	-7.32%	-9.25%	-4.19%	-0.11%	0.38%	-0.27%	-0.45%	-1.13%	-8.34%	-1.23%	-7.24%	-2.51%	-4.37%	-2.97%	-1.16%	-8.71%	-7.19%	-0.02%
Income	-2.12%	-3.48%	-1.17%	-0.13%	0.38%	-0.36%	-0.53%	-1.33%	-3.73%	-0.48%	-2.90%	-0.97%	-1.06%	-1.17%	-0.28%	-3.66%	-2.68%	0.01%
Lump-sum	4.40%	1.61%	1.14%	-0.17%	0.38%	-0.50%	-0.66%	-1.64%	1.12%	0.21%	1.42%	0.46%	1.24%	0.29%	0.32%	0.77%	1.34%	0.03%

The pattern of the previous section is repeated in this one. In this case sector e2's output actually increases in all runs, although by a small proportion. The output of all the other energy sectors falls by a larger proportion than with the consumption based energy tax. This is indeed what one would expect but the magnitude of this increased change is perhaps not as high as expected. The fall is highest for sector e5 (Gas).

There is again significant variation in the effect by the different revenue instruments and again the use of consumption taxes causes the biggest fall in energy usage.

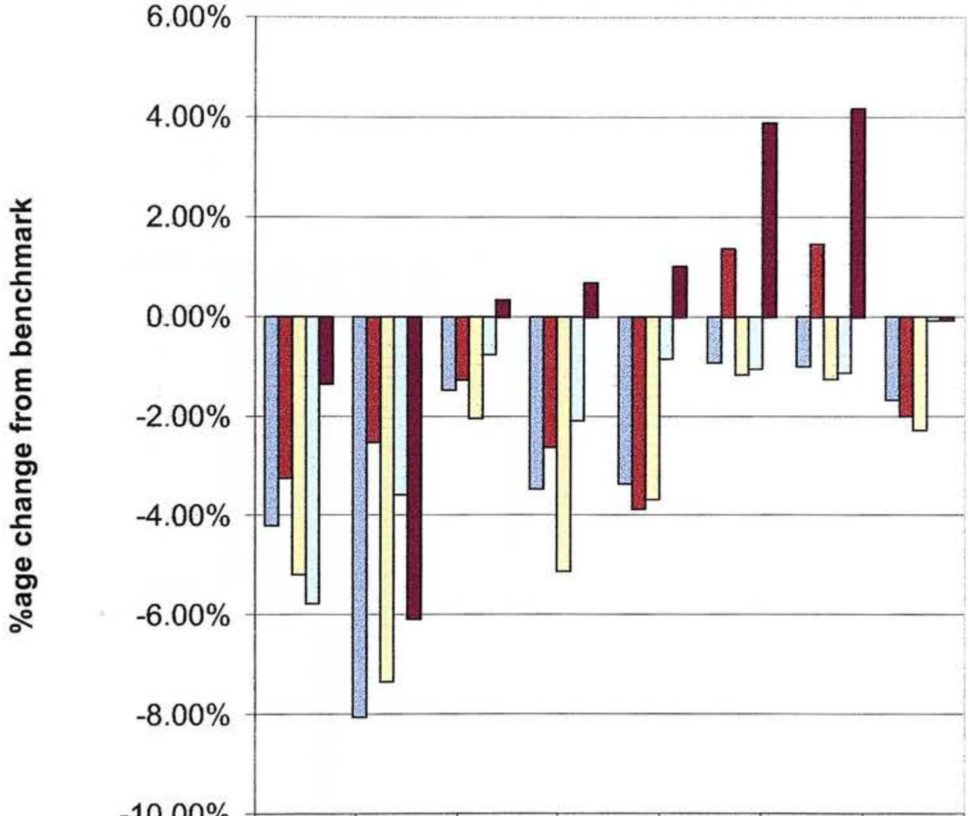
Figure 6.6 (a and b) presents changes in other selected variables. The wage level and the interest rate fall in both scenarios, but this time the effect is less linear as the effect is less than twice as strong when the energy tax rate is tripled as opposed to doubled. The return to capital falls most in this case when consumption taxes are used for recycling and the wage rate falls most when income tax is used. There is only a significant decline in the exchange rate in all instances. See Appendices.

Output falls in all cases, except lump-sum transfers where it actually increases. This is because the significantly larger revenue, when returned as a lump-sum transfer results in a large increase in consumption. Under the other recycling instruments the fall in output is largest with consumption taxes and lowest when income taxes are used.

In this case no form of the double dividend holds. The reasoning is that households include transfer payments in their leisure-effort decision and thus, as modelled, lump-sum transfers have a distortionary impact in the model. Indeed total labour supply declines by the same (low) proportion if the recycling instrument is income tax or lump-sum transfer.

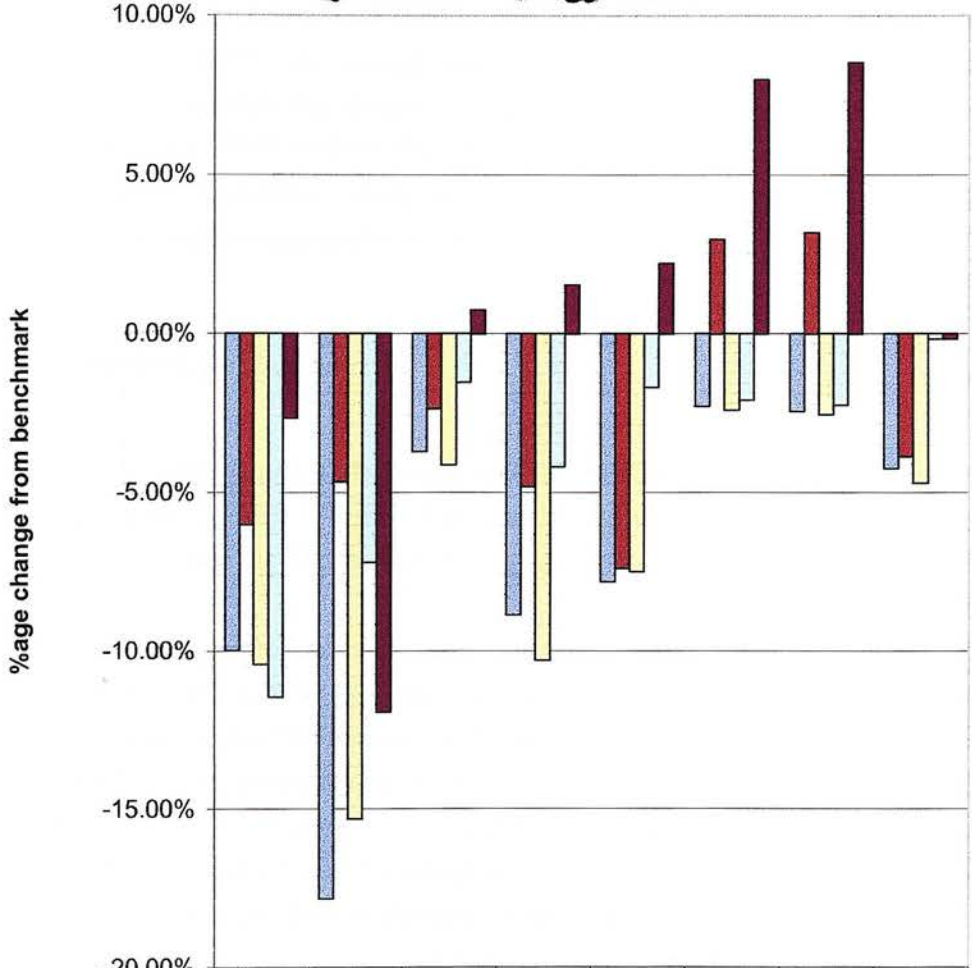
As detailed above consumption rises under lump-sum transfers and falls in all other cases. The greatest fall in consumption is caused by the reduction in corporation tax.

Figure 6.6a - Results for a doubling of producer energy taxes



	w	r	Q	C	G exp (£)	G rev (£)	T L D
C taxes	-4.19%	-8.05%	-1.48%	-3.47%	-0.93%	-0.99%	-1.66%
P Labour	-3.24%	-2.52%	-1.26%	-2.62%	1.36%	1.45%	-2.01%
Corporation	-5.19%	-7.33%	-2.04%	-5.12%	-1.17%	-1.25%	-2.27%
Income	-5.77%	-3.57%	-0.75%	-2.09%	-1.05%	-1.12%	-0.07%
Lump-sum	-1.35%	-6.08%	0.34%	0.68%	3.89%	4.16%	-0.07%

Figure 6.6b - Model results for a tripling o producer energy taxes



	w	r	Q	C	I	G exp (£)	G rev (£)	T L D
C taxes	-9.96%	-17.82	-3.69%	-8.87%	-7.82%	-2.27%	-2.42%	-4.23%
P Labour	-6.00%	-4.66%	-2.36%	-4.81%	-7.40%	2.97%	3.18%	-3.86%
Corporation	-10.41	-15.30	-4.11%	-10.30	-7.49%	-2.38%	-2.55%	-4.70%
Income	-11.45	-7.20%	-1.51%	-4.18%	-1.69%	-2.09%	-2.23%	-0.15%
Lump-sum	-2.66%	-11.92	0.75%	1.54%	2.20%	7.98%	8.54%	-0.15%

In this section changes in producer prices are not illustrated diagramatically but may be found in the Appendix. The overall producer price index falls in all runs except those where producer labour taxes are adjusted (which has been discounted). The lowest fall is with lump-sum transfers. Indeed with lump-sum transfers only energy prices fall (remember that these producer prices do not include the increased energy tax). For the other instruments, looking at individual sectors, the output price of sector e_2 rises in all cases and there is a further rises in producer prices with Alcohol rising significantly with consumption taxes as the instrument.

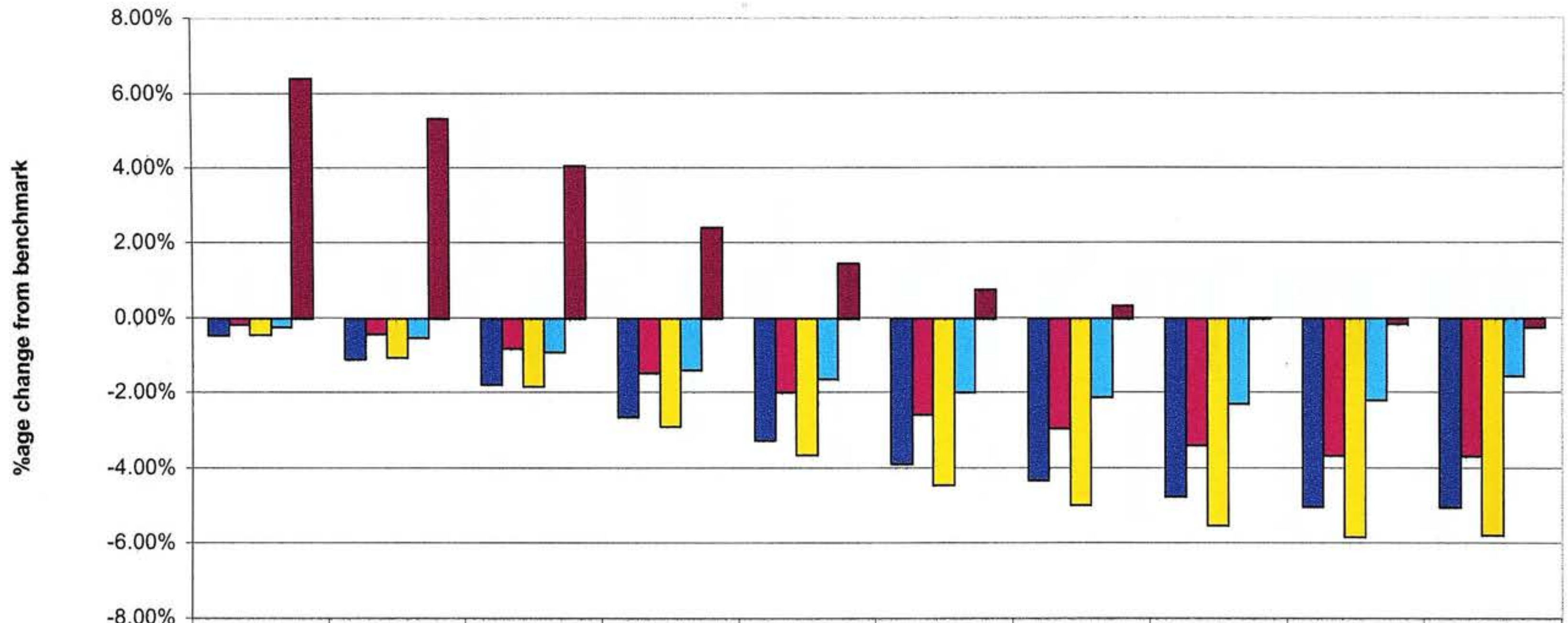
6.2.2 Distributional issues

This section considers the distributional implications of the revenue-neutral production energy tax. Figure 6.7 (a and b) shows the percentage change in household income by household income group.

The situation is very similar to that under the energy consumption tax. The only case in which any household's income rises is lump-sum transfers when all but the top 2 households receive income gains. In all cases lower income households lose proportionally less than higher income households. Although this again is somewhat offset by a greater proportionate rise in the consumer price index faced by lower income households, the net outcome is more progressive than that of the consumption energy tax.

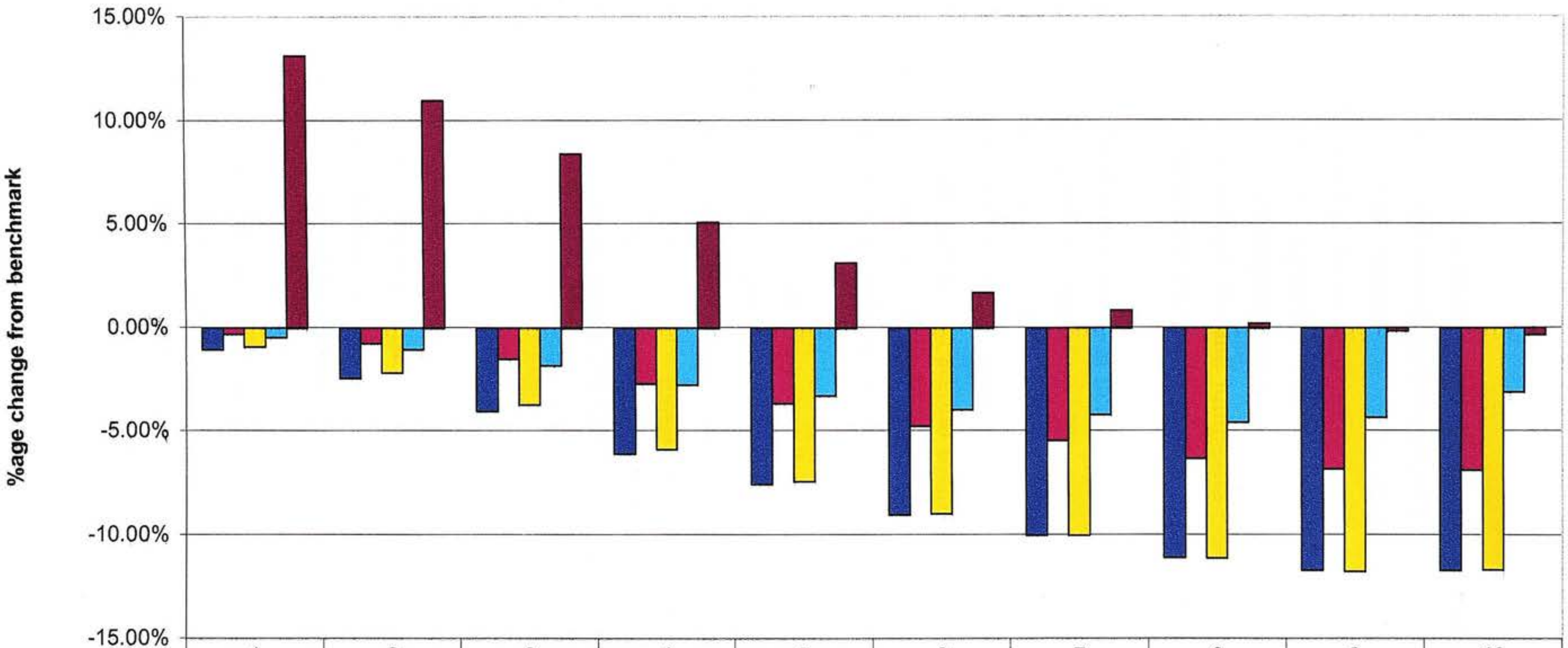
There is much less of a discernible pattern in the changes in household labour supply in the producer tax results. The households in the lower middle of the income range tend to increase their labour supply in all cases and the there are positive changes in labour supply for all but the top 4 households under lump-sum transfers.

Figure 6.7a - Changes in household income - producer energy taxes doubled



	1	2	3	4	5	6	7	8	9	10
C taxes	-0.47%	-1.10%	-1.77%	-2.64%	-3.26%	-3.88%	-4.30%	-4.75%	-5.02%	-5.03%
P Labour	-0.17%	-0.41%	-0.82%	-1.47%	-1.98%	-2.56%	-2.94%	-3.39%	-3.66%	-3.68%
Corporation	-0.45%	-1.05%	-1.82%	-2.88%	-3.66%	-4.45%	-4.97%	-5.51%	-5.83%	-5.78%
Income	-0.23%	-0.53%	-0.91%	-1.38%	-1.64%	-1.98%	-2.11%	-2.29%	-2.18%	-1.55%
Lump-sum	6.41%	5.33%	4.06%	2.43%	1.46%	0.76%	0.33%	0.01%	-0.16%	-0.25%

Figure 6.7b - Changes in household income - Producer energy taxes tripled



	1	2	3	4	5	6	7	8	9	10
C taxes	-1.05%	-2.46%	-4.03%	-6.10%	-7.56%	-9.02%	-10.02%	-11.06%	-11.68%	-11.70%
P Labour	-0.32%	-0.77%	-1.52%	-2.71%	-3.67%	-4.75%	-5.46%	-6.31%	-6.82%	-6.86%
Corporation	-0.93%	-2.19%	-3.74%	-5.88%	-7.43%	-8.99%	-10.02%	-11.10%	-11.73%	-11.65%
Income	-0.47%	-1.06%	-1.83%	-2.77%	-3.29%	-3.97%	-4.21%	-4.57%	-4.35%	-3.12%
Lump-sum	13.15%	10.98%	8.40%	5.09%	3.12%	1.69%	0.82%	0.18%	-0.16%	-0.35%

6.4 Conclusions

This chapter has presented the results of the applied general equilibrium model outlined in the preceding two chapters. Two forms of revenue neutral energy taxation were examined using the model - an energy tax on consumer prices and an energy tax on producer prices. In each case revenue neutrality was achieved by adjusting one of five possible revenue recycling instruments - consumption (non-energy) taxes, producer labour taxes, corporation tax, income tax and lump-sum transfers. Thus, 20 runs of the model were undertaken and analysed.

The results for the consumption tax were relatively straightforward and in keeping with the existing literature. The strong form of the second dividend was not found to exist. However, all the tax based revenue recycling instruments were preferable to lump-sum transfers in terms of the effect on output. This is equivalent to a second dividend of an improvement in the efficiency of the *rest* of the tax system. The weak form of the double dividend hypothesis, as defined by Goulder (1995) was found to hold.

With an energy tax on producer prices the results were less in keeping with the literature. It was found that the double dividend did not exist in any form and that lump-sum transfer was preferable as the revenue recycling instrument. The reason for this is that the significant revenue raised from the energy tax, when redistributed to households in a lump-sum fashion causes a substantial increase in consumption and thus output. This result is driven by the inclusion of transfer payments as a form of household income.

The formulation of the production functions in the model may also have an impact. The modelling of energy as a direct input into production along with labour and capital is a sensible approach. The complicated nature of the model and its 'black-box' characteristics mean that the effect of this functional form may not be determined. Intuitively however, the alternative approach of having energy as a fixed co-efficient inside an intermediate use matrix means that the only way in which energy use in the production sector can be reduced is by a reduction in output. Here in the case of lump-sum transfer of the revenues of a producer energy tax, output generally increases whilst the output of the energy sectors decline. The ability to capture this sort of effect is a key characteristic of the model.

Turning to distributional issues, the results of the model suggest that fears that revenue-neutral environmental tax reform will have a regressive effect are unfounded. Regardless of the revenue recycling instrument used, the changes to the income distribution are progressive in nature. This result is driven by the uncontroversial assertion that lower income households receive a greater proportion of their income form transfer payments are so are less exposed to changes in the payments to labour and capital.

Lump-sum transfers are found to be preferable in distributional terms, but as outlined above any recycling instrument produces a lower relative loss or higher relative gain to lower income households.

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[1]The simple imposition of an energy tax, as used in the sensitivity analysis is not considered as it represents a net 'disappearance' from the model. This could be considered to be an alternative use of government revenue, e.g., debt repayment, ut as this is not modelled explicitly, it is preferable to concentrate on instances where revenue is returned.

[2]As a matter of technical interest, each run takes around 20 minutes to converge to a solution on a 200 MHz Pentium II with 32 MB of RAM. Each run is calculated twice in order to ensure that the model is obtaining consistent results. In all cases this repetition process gave identical solutions.

[3]The effect is identical with both consumption taxes and income under scenario 1 but in scenario 2 the fall in output is lower with income taxes.

[4]Unfortunately, it will be see in the following section that the producer labour tax rate requires a rise in its level to achieve revenue neutrality.

[5]This result was examined in detail and does not appear to be an error in the formulation of the model or solution procedure.

Appendix 6a - Model results for a doubling of current consumption taxes

		Revenue returning instrument					Percentage changes from baseline				
	Baseline	C taxes	P Labour	Corporation	Income	Lump-sum	C taxes	P Labour	Corporation	Income	Lump-sum
Instrument	-	-0.05793	0.139957	0.3724301	0.969621	1.013895					
w	0.909091	0.892959	0.89034	0.8923359	0.882106	0.888194	-1.77%	-2.06%	-1.84%	-2.97%	-2.30%
r	1	0.968142	0.982727	0.984151	0.979833	0.961687	-3.19%	-1.73%	-1.58%	-2.02%	-3.83%
E	1	1	1	0.9999998	1	1	0.00%	0.00%	0.00%	0.00%	0.00%
Q	921786.9	916365.9	914340.8	915421.54	916381.3	914888.2	-0.59%	-0.81%	-0.69%	-0.59%	-0.75%
Q P index	1	0.990204	1.001897	0.989504	0.9884	0.987733	-0.98%	0.19%	-1.05%	-1.16%	-1.23%
Q P t index	1.051586	1.041964	1.053683	1.0412564	1.04013	1.039497	-0.91%	0.20%	-0.98%	-1.09%	-1.15%
C P Index	1.116322	1.117264	1.118474	1.115966	1.116295	1.11569	0.08%	0.19%	-0.03%	0.00%	-0.06%
C	293159.3	289303.2	287935.3	288039.32	288739.6	287713	-1.32%	-1.78%	-1.75%	-1.51%	-1.86%
G	104994.2	104994.2	104994.2	104994.18	104994.2	104994.2	0.00%	0.00%	0.00%	0.00%	0.00%
I	104426.7	102861.7	102204.5	103181.23	103440.7	102974.2	-1.50%	-2.13%	-1.19%	-0.94%	-1.39%
X	128586.2	128586.2	128586.2	128586.23	128586.2	128586.2	0.00%	0.00%	0.00%	0.00%	0.00%
M	143322.9	143322.9	143322.9	143322.89	143322.9	143322.9	0.00%	0.00%	0.00%	0.00%	0.00%
G exp (£)	277885.3	276582.6	278491.4	276507.2	276080.7	278482.3	-0.47%	0.22%	-0.50%	-0.65%	0.21%
G rev (£)	259782.9	258480.3	260389.1	258404.88	257978.4	260380	-0.50%	0.23%	-0.53%	-0.69%	0.23%
T L D	310481.9	308089	306770.3	307601.54	309107.7	307497.3	-0.77%	-1.20%	-0.93%	-0.44%	-0.96%
Prices (raw)											
a	1	0.990343	0.998481	0.9894919	0.99109	0.988131	-0.97%	-0.15%	-1.05%	-0.89%	-1.19%
c	1	0.993565	1.005198	0.9933017	0.989423	0.991686	-0.64%	0.52%	-0.67%	-1.06%	-0.83%
d	1	0.987507	0.994522	0.9862457	0.991086	0.984903	-1.25%	-0.55%	-1.38%	-0.89%	-1.51%
e1	1	0.992742	1.004929	0.9923995	0.988749	0.990681	-0.73%	0.49%	-0.76%	-1.13%	-0.93%
e2	1	0.974098	0.992281	0.9716509	0.978793	0.968474	-2.59%	-0.77%	-2.83%	-2.12%	-3.15%
e3	1	0.984738	0.997657	0.9833953	0.985768	0.981311	-1.53%	-0.23%	-1.66%	-1.42%	-1.87%
e4	1	0.990864	1.004125	0.9903451	0.987205	0.988407	-0.91%	0.41%	-0.97%	-1.28%	-1.16%
e5	1	0.984161	1.001604	0.9829617	0.982258	0.980331	-1.58%	0.16%	-1.70%	-1.77%	-1.97%
f	1	0.9939	1.004239	0.99362	0.990464	0.992168	-0.61%	0.42%	-0.64%	-0.95%	-0.78%
g	1	0.985864	1.009037	0.9851638	0.978594	0.981888	-1.41%	0.90%	-1.48%	-2.14%	-1.81%
hd	1	0.977817	0.995054	0.9757958	0.980647	0.972854	-2.22%	-0.49%	-2.42%	-1.94%	-2.71%
o	1	0.993799	1.004788	0.9935362	0.989964	0.992005	-0.62%	0.48%	-0.65%	-1.00%	-0.80%
oc	1	0.987546	0.998054	0.9864441	0.988532	0.984686	-1.25%	-0.19%	-1.36%	-1.15%	-1.53%
s	1	0.991736	1.001225	0.9911187	0.990547	0.989657	-0.83%	0.12%	-0.89%	-0.95%	-1.03%
sb	1	0.992984	1.005121	0.9926686	0.988894	0.99097	-0.70%	0.51%	-0.73%	-1.11%	-0.90%
t	1	0.994194	1.002752	0.9938681	0.991868	0.992632	-0.58%	0.28%	-0.61%	-0.81%	-0.74%
z	1	0.992761	1.005124	0.9924306	0.988641	0.990697	-0.72%	0.51%	-0.76%	-1.14%	-0.93%
zm	1	0.995362	1.002228	0.9951004	0.993492	0.99411	-0.46%	0.22%	-0.49%	-0.65%	-0.59%
QD - Output by sector							C taxes	P Labour	Corporation	Income	Lump-sum
a	8038.752	8329.615	7978.702	7981.6229	7996.225	7983.409	3.62%	-0.75%	-0.71%	-0.53%	-0.69%
c	10013.31	10016.74	9863.786	9866.8315	9890.624	9853.243	0.03%	-1.49%	-1.46%	-1.23%	-1.60%
d	77388.42	76767.01	76587.07	76861.472	76958.41	76795.01	-0.80%	-1.04%	-0.68%	-0.56%	-0.77%
e1	3828.899	3813.76	3825.56	3825.56	3825.44	3825.64	-0.40%	-0.09%	-0.09%	-0.09%	-0.09%
e2	11812.04	11812.05	11812.05	11812.05	11812.05	11812.05	0.00%	0.00%	0.00%	0.00%	0.00%
e3	11088.18	10942.88	11056.13	11056.13	11054.95	11056.91	-1.31%	-0.29%	-0.29%	-0.30%	-0.28%
e4	22105.07	21838.60	22046.26	22046.26	22044.11	22047.69	-1.21%	-0.27%	-0.27%	-0.28%	-0.26%
e5	6980.809	6774.31	6935.24	6935.24	6933.57	6936.35	-2.96%	-0.65%	-0.65%	-0.68%	-0.64%
f	56290.51	55383.73	55382.47	55400.173	55491.93	55381.28	-1.61%	-1.61%	-1.58%	-1.42%	-1.62%
g	79013.71	78889.83	78853.15	78856.622	78879.67	78845.32	-0.16%	-0.20%	-0.20%	-0.17%	-0.21%
hd	39382.93	38896.7	38901.6	38912.303	38977.19	38888.61	-1.23%	-1.22%	-1.19%	-1.03%	-1.26%
o	45684.05	45536.32	45492.57	45496.844	45524.33	45483.36	-0.32%	-0.42%	-0.41%	-0.35%	-0.44%
oc	103756.8	102863.6	102521.5	103032.76	103178.4	102921	-0.86%	-1.19%	-0.70%	-0.56%	-0.81%
s	173169	172510.7	172272.7	172290.56	172421.6	172208.9	-0.38%	-0.52%	-0.51%	-0.43%	-0.55%
sb	48677.7	48569.44	48524.49	48586.845	48605.08	48572.6	-0.22%	-0.31%	-0.19%	-0.15%	-0.22%
t	48416.18	47935	47633.26	47653.928	47752.8	47593.38	-0.99%	-1.62%	-1.57%	-1.37%	-1.70%
z	125209.3	123987.1	123600.9	123752.9	123976.3	123633.3	-0.98%	-1.28%	-1.16%	-0.98%	-1.26%
zm	50931.23	50928.41	50927.58	50927.654	50928.18	50927.4	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%
HLD - Household labour supply											
1	207	206.8871	206.7541	206.751	206.1314	206.785	-0.05%	-0.12%	-0.12%	-0.42%	-0.10%
2	640	640.8335	639.8248	639.7746	639.2748	640.655	0.13%	-0.03%	-0.04%	-0.11%	0.10%
3	3470	3477.663	3469.753	3469.5787	3471.154	3476.574	0.22%	-0.01%	-0.01%	0.03%	0.19%
4	10348	10358	10332.51	10333.368	10354.27	10353.21	0.10%	-0.15%	-0.14%	0.06%	0.05%
5	18551	18529.85	18481.88	18489.615	18545.08	18515.29	-0.11%	-0.37%	-0.33%	-0.03%	-0.19%
6	28978	28850.83	28771.43	28800.535	28901.75	28812.96	-0.44%	-0.71%	-0.61%	-0.26%	-0.57%
7	37653	37417.6	37296.99	37357.319	37505.11	37356.32	-0.63%	-0.95%	-0.79%	-0.39%	-0.79%
8	48300	47877.36	47690.21	47811.068	48013.11	47777.17	-0.88%	-1.26%	-1.01%	-0.59%	-1.08%
9	61274	60646.44	60376.82	60569.212	60877.41	60503.29	-1.02%	-1.46%	-1.15%	-0.65%	-1.26%
10	101061	100083.5	99504.1	99924.322	100594.4	99855.06	-0.97%	-1.54%	-1.12%	-0.46%	-1.19%

HP -Consumption price index											
1	1.160835	1.162555	1.163336	1.1627474	1.162837	1.162659	0.15%	0.22%	0.16%	0.17%	0.16%
2	1.158564	1.16064	1.161141	1.1605535	1.160643	1.160465	0.18%	0.22%	0.17%	0.18%	0.16%
3	1.148448	1.151204	1.151097	1.1505145	1.150603	1.150427	0.24%	0.23%	0.18%	0.19%	0.17%
4	1.143039	1.145626	1.145614	1.1446269	1.144778	1.144478	0.23%	0.23%	0.14%	0.15%	0.13%
5	1.138112	1.140586	1.140648	1.1393931	1.139585	1.139204	0.22%	0.22%	0.11%	0.13%	0.10%
6	1.125859	1.128004	1.128215	1.1265809	1.12683	1.126335	0.19%	0.21%	0.06%	0.09%	0.04%
7	1.117076	1.118283	1.119168	1.1168198	1.117178	1.116466	0.11%	0.19%	-0.02%	0.01%	-0.05%
8	1.107481	1.107925	1.109336	1.1063988	1.106847	1.105957	0.04%	0.17%	-0.10%	-0.06%	-0.14%
9	1.10145	1.101497	1.103172	1.0999231	1.100419	1.099434	0.00%	0.16%	-0.14%	-0.09%	-0.18%
10	1.083802	1.082067	1.085011	1.0803994	1.081103	1.079706	-0.16%	0.11%	-0.31%	-0.25%	-0.38%
HNI - Household net income											
1	12646.23	12622.73	12631.42	12632.709	12629.49	12782.06	-0.19%	-0.12%	-0.11%	-0.13%	1.07%
2	15980.43	15910.63	15936.17	15940.028	15931.54	16083.31	-0.44%	-0.28%	-0.25%	-0.31%	0.64%
3	21397.41	21245.86	21282.29	21292.964	21280.41	21420.8	-0.71%	-0.54%	-0.49%	-0.55%	0.11%
4	26924.95	26635.95	26669.24	26693.769	26688.9	26757.87	-1.07%	-0.95%	-0.86%	-0.88%	-0.62%
5	33964.3	33507.66	33529.86	33573.593	33591.54	33583.53	-1.34%	-1.28%	-1.15%	-1.10%	-1.12%
6	41983.06	41299.73	41291.8	41367.025	41409.39	41317.44	-1.63%	-1.65%	-1.47%	-1.37%	-1.59%
7	49606.75	48703.91	48672.2	48782.97	48863.58	48673.66	-1.82%	-1.88%	-1.66%	-1.50%	-1.88%
8	59022.54	57827.1	57750.02	57918.466	58041.38	57740.4	-2.03%	-2.16%	-1.87%	-1.66%	-2.17%
9	71663.95	70125.04	70003.46	70238.479	70464.56	69988.13	-2.15%	-2.32%	-1.99%	-1.67%	-2.34%
10	121536.8	118932.1	118739.7	119188.44	119816.6	118699.8	-2.14%	-2.30%	-1.93%	-1.42%	-2.33%
Food											
Total	61166.66	60259.88	60258.62	60276.321	60368.08	60257.43	-1.48%	-1.48%	-1.46%	-1.31%	-1.49%
1	2747.536	2741.732	2738.442	2738.1328	2737.659	2763.811	-0.21%	-0.33%	-0.34%	-0.36%	0.59%
2	3364.242	3349.648	3348.568	3348.5638	3347.259	3372.131	-0.43%	-0.47%	-0.47%	-0.50%	0.23%
3	4288.012	4259.584	4259.002	4259.8532	4258.029	4279.543	-0.66%	-0.68%	-0.66%	-0.70%	-0.20%
4	4251.976	4206.599	4209.326	4210.7604	4210.415	4217.862	-1.07%	-1.00%	-0.97%	-0.98%	-0.80%
5	5704.18	5634.5	5633.397	5636.3365	5638.967	5637.195	-1.22%	-1.24%	-1.19%	-1.14%	-1.17%
6	6566.139	6471.174	6466.999	6471.6094	6477.131	6465.259	-1.45%	-1.51%	-1.44%	-1.36%	-1.54%
7	7078.485	6963.323	6959.661	6963.9839	6973.523	6951.454	-1.63%	-1.68%	-1.62%	-1.48%	-1.79%
8	7731.061	7590.648	7586.378	7591.2444	7604.651	7572.603	-1.82%	-1.87%	-1.81%	-1.64%	-2.05%
9	8597.003	8430.679	8427.275	8432.9345	8454.526	8409.272	-1.93%	-1.97%	-1.91%	-1.66%	-2.18%
10	10838.03	10611.99	10629.57	10622.902	10665.92	10588.3	-2.09%	-1.92%	-1.98%	-1.59%	-2.30%
Alc											
Total	6075.122	6365.984	6015.071	6017.9922	6032.595	6019.778	4.79%	-0.99%	-0.94%	-0.70%	-0.91%
1	456.222	479.6265	457.6454	457.57198	457.4596	463.6767	5.13%	0.31%	0.30%	0.27%	1.63%
2	525.5059	551.6613	526.4317	526.43083	526.1322	531.8358	4.98%	0.18%	0.18%	0.12%	1.20%
3	528.3979	555.4163	528.4667	528.62956	528.2806	532.4024	5.11%	0.01%	0.04%	-0.02%	0.76%
4	573.0704	600.8845	570.6554	570.98355	570.9045	572.6099	4.85%	-0.42%	-0.36%	-0.38%	-0.08%
5	614.985	644.4068	610.3391	610.87612	611.3568	611.033	4.78%	-0.76%	-0.67%	-0.59%	-0.64%
6	593.1431	621.9021	586.4728	587.21539	588.1052	586.1928	4.85%	-1.12%	-1.00%	-0.85%	-1.17%
7	637.3985	666.6511	628.3274	629.03143	630.5863	626.9917	4.59%	-1.42%	-1.31%	-1.07%	-1.63%
8	644.8803	673.8684	633.6212	634.38001	636.4728	631.4755	4.50%	-1.75%	-1.63%	-1.30%	-2.08%
9	670.1504	700.8958	657.2386	658.10257	661.4039	654.4939	4.59%	-1.93%	-1.80%	-1.31%	-2.34%
10	831.3683	870.6717	815.8726	814.77074	821.8929	809.0664	4.73%	-1.86%	-2.00%	-1.14%	-2.68%
Fuel											
Total	1269.67	1200.557	1254.418	1254.4182	1253.86	1254.789	-5.44%	-1.20%	-1.20%	-1.25%	-1.17%
1	46.08012	43.45468	45.3759	45.376208	45.37668	45.34744	-5.70%	-1.53%	-1.53%	-1.53%	-1.59%
2	54.40968	51.19329	53.62589	53.625897	53.62951	53.55798	-5.91%	-1.44%	-1.44%	-1.43%	-1.57%
3	75.11979	70.83104	74.04787	74.045867	74.05015	73.99802	-5.71%	-1.43%	-1.43%	-1.42%	-1.49%
4	101.3089	95.85156	99.75728	99.75734	99.75733	99.7573	-5.39%	-1.53%	-1.53%	-1.53%	-1.53%
5	127.7964	120.9991	125.8058	125.80764	125.8093	125.8082	-5.32%	-1.56%	-1.56%	-1.55%	-1.56%
6	141.779	134.1567	139.7521	139.74746	139.7417	139.7538	-5.38%	-1.43%	-1.43%	-1.44%	-1.43%
7	155.4252	147.0947	153.2519	153.24666	153.2347	153.2615	-5.36%	-1.40%	-1.40%	-1.41%	-1.39%
8	160.3144	151.6277	158.4764	158.45919	158.4111	158.5243	-5.42%	-1.15%	-1.16%	-1.19%	-1.12%
9	174.4281	164.9322	172.8515	172.81995	172.6978	172.9506	-5.44%	-0.90%	-0.92%	-0.99%	-0.85%
10	233.0081	220.416	231.4738	231.53199	231.1514	231.8297	-5.40%	-0.66%	-0.63%	-0.80%	-0.51%
Clothing											
Total	6400.713	6404.135	6251.186	6254.2316	6278.024	6240.643	0.05%	-2.34%	-2.29%	-1.92%	-2.50%
1	131.4908	134.8901	131.7615	131.72919	131.6797	134.4217	2.59%	0.21%	0.18%	0.14%	2.23%
2	213.7063	218.3836	213.4573	213.45676	213.2901	216.4761	2.19%	-0.12%	-0.12%	-0.19%	1.30%
3	304.2415	309.5205	302.6178	302.73843	302.4799	305.5353	1.74%	-0.53%	-0.49%	-0.58%	0.43%
4	387.6505	392.0705	383.1475	383.42293	383.3565	384.7885	1.14%	-1.16%	-1.09%	-1.11%	-0.74%
5	547.7642	552.0786	538.9143	539.46673	539.9613	539.6282	0.79%	-1.62%	-1.51%	-1.42%	-1.49%
6	613.551	615.2523	600.1969	601.0587	602.0915	599.872	0.28%	-2.18%	-2.04%	-1.87%	-2.23%
7	708.4074	708.1158	690.7112	691.57078	693.4695	689.0803	-0.04%	-2.50%	-2.38%	-2.11%	-2.73%
8	843.9874	840.9663	819.9391	820.98201	823.8585	816.9903	-0.36%	-2.85%	-2.73%	-2.38%	-3.20%
9	1053.469	1048.095	1021.571	1022.9255	1028.101	1017.269	-0.51%	-3.03%	-2.90%	-2.41%	-3.44%
10	1596.445	1584.763	1548.87	1546.8807	1559.737	1536.582	-0.73%	-2.98%	-3.10%	-2.30%	-3.75%
Transport											
Total	28393.8	27922.89	27625.47	27639.722	27736.89	27580.53	-1.66%	-2.71%	-2.66%	-2.31%	-2.86%
1	443.0082	447.9337	439.5937	439.48108	439.3085	448.8691	1.11%	-0.77%	-0.80%	-0.84%	1.32%
2	709.2316	713.0272	702.8109	702.80915	702.2361	713.1931	0.54%	-0.91%	-0.91%	-0.99%	0.56%
3	1325.653	1325.604	1310.899	1311.3944	1310.333	1322.876	0.00%	-1.11%	-1.08%	-1.16%	-0.21%
4	1962.046	1950.939	1931.062	1932.3218	1932.018	1938.569	-0.57%	-1.58%	-1.51%	-1.53%	-1.20%
5	2580.196	2555.519	2528.876	2531.2933	2533.458	2532	-0.96%	-1.99%	-1.90%	-1.81%	-1.87%
6	3053.338	3011.271	2977.567	2981.4836	2986.177	2976.09	-1.38%	-2.48%	-2.35%	-2.20%	-2.53%
7	3510.436	3451.167	3413.382	3417.2881	3425.915	3405.971	-1.69%	-2.76%	-2.65%	-2.41%	-2.98%
8	3924.444	3844.585	3801.625	3806.1595	3818.666	3788.802	-2.03%	-3.13%	-3.01%	-2.70%	-3.46%
9	4529.235	4427.368	4377.351	4382.9216	4404.204	4359.656	-2.25%	-3.35%	-3.23%	-2.76%	-3.74%
10	6356.214	6195.48	6142.306	6134.5697	6184.573	6094.51	-2.53%	-3.37%	-3.49%	-2.70%	-4.12%

Other											
Total	101495	100196.2	99811.83	99848.17	100089.8	99729.69	-1.28%	-1.66%	-1.62%	-1.38%	-1.74%
1	3139.71	3150.454	3137.97	3137.5299	3136.855	3174.136	0.34%	-0.06%	-0.07%	-0.09%	1.10%
2	4106.815	4110.619	4097.998	4097.9919	4095.984	4134.317	0.09%	-0.21%	-0.21%	-0.26%	0.67%
3	5746.12	5735.932	5718.802	5720.2625	5717.134	5754.071	-0.18%	-0.48%	-0.45%	-0.50%	0.14%
4	7316.732	7276.026	7252.083	7255.4682	7254.652	7272.243	-0.56%	-0.88%	-0.84%	-0.85%	-0.61%
5	8778.214	8704.986	8672.312	8678.335	8683.726	8680.095	-0.83%	-1.21%	-1.14%	-1.08%	-1.12%
6	10832.71	10709.68	10662.39	10672.596	10684.82	10658.55	-1.14%	-1.57%	-1.48%	-1.37%	-1.61%
7	11456.37	11299.68	11249.84	11259.297	11280.17	11231.9	-1.37%	-1.80%	-1.72%	-1.54%	-1.96%
8	12883.88	12675.15	12616.82	12627.872	12658.33	12585.57	-1.62%	-2.07%	-1.99%	-1.75%	-2.32%
9	15836.88	15555.68	15482.58	15497.02	15552.17	15436.67	-1.78%	-2.24%	-2.15%	-1.80%	-2.53%
10	21397.52	20978.02	20921.02	20901.796	21025.99	20802.15	-1.96%	-2.23%	-2.32%	-1.74%	-2.78%
Sevices											
Total	44037.81	43378.61	43140.74	43153.94	43285.45	43072.24	-1.50%	-2.04%	-2.01%	-1.71%	-2.19%
1	995.5311	1001.334	993.3061	993.14694	992.9031	1006.388	0.58%	-0.22%	-0.24%	-0.26%	1.09%
2	1332.957	1336.587	1327.637	1327.6353	1326.896	1341.014	0.27%	-0.40%	-0.40%	-0.45%	0.60%
3	1897.859	1896.584	1884.867	1885.4101	1884.246	1897.994	-0.07%	-0.68%	-0.66%	-0.72%	0.01%
4	2775.946	2760.386	2745.135	2746.5557	2746.213	2753.599	-0.56%	-1.11%	-1.06%	-1.07%	-0.81%
5	3298.826	3270.426	3250.046	3252.5598	3254.81	3253.294	-0.86%	-1.48%	-1.40%	-1.33%	-1.38%
6	4017.885	3969.436	3942.594	3946.7807	3951.797	3941.015	-1.21%	-1.87%	-1.77%	-1.64%	-1.91%
7	4992.84	4918.304	4887.797	4892.3129	4902.284	4879.228	-1.49%	-2.10%	-2.01%	-1.81%	-2.28%
8	5889.648	5784.813	5749.098	5754.608	5769.801	5733.511	-1.78%	-2.39%	-2.29%	-2.03%	-2.65%
9	6544.73	6417.764	6376.324	6382.8545	6407.796	6355.57	-1.94%	-2.57%	-2.47%	-2.09%	-2.89%
10	12291.59	12022.98	11983.94	11972.076	12048.7	11910.62	-2.19%	-2.50%	-2.60%	-1.98%	-3.10%
Durables											
Total	44426.54	43675.14	43682.73	43699.261	43799.54	43662.65	-1.69%	-1.67%	-1.64%	-1.41%	-1.72%
1	1854.84	1852.673	1852.724	1852.4618	1852.06	1874.293	-0.12%	-0.11%	-0.13%	-0.15%	1.05%
2	2146.719	2138.839	2140.843	2140.8394	2139.78	2160.004	-0.37%	-0.27%	-0.27%	-0.32%	0.62%
3	2788.435	2770.672	2773.528	2774.2431	2772.711	2790.795	-0.64%	-0.53%	-0.51%	-0.56%	0.08%
4	3238.779	3205.873	3208.208	3209.7191	3209.355	3217.208	-1.02%	-0.94%	-0.90%	-0.91%	-0.67%
5	3795.015	3745.784	3746.754	3749.3811	3751.732	3750.149	-1.30%	-1.27%	-1.20%	-1.14%	-1.18%
6	4842.311	4764.945	4763.011	4767.6095	4773.118	4761.277	-1.60%	-1.64%	-1.54%	-1.43%	-1.67%
7	5093.97	5000.568	4998.553	5002.7936	5012.156	4990.505	-1.83%	-1.87%	-1.79%	-1.61%	-2.03%
8	5467.446	5353.349	5350.161	5354.8897	5367.926	5336.783	-2.09%	-2.15%	-2.06%	-1.82%	-2.39%
9	6657.749	6508.648	6504.161	6510.2818	6533.656	6484.704	-2.24%	-2.31%	-2.21%	-1.86%	-2.60%
10	8541.276	8333.792	8344.783	8337.0418	8387.041	8296.928	-2.43%	-2.30%	-2.39%	-1.81%	-2.86%

Appendix 6b - Model results for a tripling of current consumption taxes

		Revenue returning instrument					Percentage changes from baseline				
	Baseline	C taxes	P Labour	Corporation	Income	Lump-sum	C taxes	P Labour	Corporation	Income	Lump-sum
Instrument	-	-0.11555	0.18072	0.3501935	0.939562	1.026514					
w	0.909091	0.87602	0.872567	0.8746141	0.855761	0.86754	-3.64%	-4.02%	-3.79%	-5.87%	-4.57%
r	1	0.934882	0.966532	0.9639954	0.958759	0.923766	-6.51%	-3.35%	-3.60%	-4.12%	-7.62%
E	1	1	1	0.9999998	1	1	0.00%	0.00%	0.00%	0.00%	0.00%
Q	921786.9	910620.7	907285.8	908538.11	910870	907936.5	-1.21%	-1.57%	-1.44%	-1.18%	-1.50%
Q P index	1	0.979852	1.00378	0.9785975	0.976847	0.975464	-2.01%	0.38%	-2.14%	-2.32%	-2.45%
Q P t index	1.051586	1.031797	1.05576	1.0305312	1.028724	1.027408	-1.88%	0.40%	-2.00%	-2.17%	-2.30%
C P Index	1.116322	1.118105	1.120661	1.1155279	1.116207	1.115044	0.16%	0.39%	-0.07%	-0.01%	-0.11%
C	293159.3	285193.4	283003.5	282549.16	284248.5	282231.4	-2.72%	-3.46%	-3.62%	-3.04%	-3.73%
G	104994.2	104994.2	104994.2	104994.18	104994.2	104994.2	0.00%	0.00%	0.00%	0.00%	0.00%
I	104426.7	101226.4	100081.3	101787.96	102420.5	101504.1	-3.06%	-4.16%	-2.53%	-1.92%	-2.80%
X	128586.2	128586.2	128586.2	128586.23	128586.2	128586.2	0.00%	0.00%	0.00%	0.00%	0.00%
M	143322.9	143322.9	143322.9	143322.89	143322.9	143322.9	0.00%	0.00%	0.00%	0.00%	0.00%
G exp (£)	277885.3	275209.7	279115	275065.26	274302.5	278881.3	-0.96%	0.44%	-1.01%	-1.29%	0.36%
G rev (£)	259782.9	257107.3	261012.6	256962.94	256200.1	260779	-1.03%	0.47%	-1.09%	-1.38%	0.38%
T L D	310481.9	305513.5	303232.1	304560.35	307645	304441	-1.60%	-2.34%	-1.91%	-0.91%	-1.95%
Prices (raw)											
a	1	0.980115	0.997078	0.9787063	0.982035	0.976213	-1.99%	-0.29%	-2.13%	-1.80%	-2.38%
c	1	0.986808	1.010352	0.9862235	0.979091	0.983466	-1.32%	1.04%	-1.38%	-2.09%	-1.65%
d	1	0.974521	0.989661	0.9725597	0.98195	0.97005	-2.55%	-1.03%	-2.74%	-1.80%	-3.00%
e1	1	0.985085	1.009362	0.9843671	0.977737	0.981414	-1.49%	0.94%	-1.56%	-2.23%	-1.86%
e2	1	0.947125	0.984894	0.9432279	0.957332	0.937421	-5.29%	-1.51%	-5.68%	-4.27%	-6.26%
e3	1	0.968661	0.993111	0.9664184	0.971401	0.962646	-3.13%	-0.69%	-3.36%	-2.86%	-3.74%
e4	1	0.981186	1.00574	0.9801767	0.974575	0.976806	-1.88%	0.57%	-1.98%	-2.54%	-2.32%
e5	1	0.967544	1.001551	0.9654537	0.964594	0.960814	-3.25%	0.16%	-3.45%	-3.54%	-3.92%
f	1	0.987486	1.00811	0.9868963	0.981132	0.984408	-1.25%	0.81%	-1.31%	-1.89%	-1.56%
g	1	0.970962	1.018306	0.9695284	0.957594	0.963884	-2.90%	1.83%	-3.05%	-4.24%	-3.61%
hd	1	0.954554	0.991041	0.951282	0.961049	0.945906	-4.54%	-0.90%	-4.87%	-3.90%	-5.41%
o	1	0.987286	1.009419	0.9867122	0.980156	0.984097	-1.27%	0.94%	-1.33%	-1.98%	-1.59%
oc	1	0.974309	0.996468	0.9724775	0.976862	0.969247	-2.57%	-0.35%	-2.75%	-2.31%	-3.08%
s	1	0.982816	1.002615	0.9817047	0.981023	0.979062	-1.72%	0.26%	-1.83%	-1.90%	-2.09%
sb	1	0.985595	1.010276	0.9849212	0.978029	0.982009	-1.44%	1.03%	-1.51%	-2.20%	-1.80%
t	1	0.988041	1.00488	0.987403	0.983861	0.985255	-1.20%	0.49%	-1.26%	-1.61%	-1.47%
z	1	0.985141	1.010076	0.9844407	0.977525	0.981467	-1.49%	1.01%	-1.56%	-2.25%	-1.85%
zm	1	0.990433	1.004043	0.9899174	0.987078	0.988193	-0.96%	0.40%	-1.01%	-1.29%	-1.18%
QD - Output by sector							C taxes	P Labour	Corporation	Income	Lump-sum
a	8038.752	8633.525	7922.751	7912.4635	7949.251	7923.359	7.40%	-1.44%	-1.57%	-1.11%	-1.44%
c	10013.31	10011.52	9723.613	9708.3346	9765.278	9692.528	-0.02%	-2.89%	-3.05%	-2.48%	-3.20%
d	77388.42	76116.7	75823.61	76279.453	76515.96	76194.72	-1.64%	-2.02%	-1.43%	-1.13%	-1.54%
e1	3828.899	3799.029	3822.123	3822.1901	3821.964	3822.275	-0.78%	-0.18%	-0.18%	-0.18%	-0.17%
e2	11812.04	11812.05	11812.05	11812.053	11812.05	11812.05	0.00%	0.00%	0.00%	0.00%	0.00%
e3	11088.18	10801.52	11023.16	11023.797	11021.63	11024.61	-2.59%	-0.59%	-0.58%	-0.60%	-0.57%
e4	22105.07	21579.38	21985.81	21986.982	21983	21988.47	-2.38%	-0.54%	-0.53%	-0.55%	-0.53%
e5	6980.809	6573.416	6888.388	6889.2971	6886.211	6890.454	-5.84%	-1.32%	-1.31%	-1.36%	-1.29%
f	56290.51	54433.55	54519.55	54458.985	54687.4	54465.55	-3.30%	-3.15%	-3.25%	-2.85%	-3.24%
g	79013.71	78756.05	78701.59	78686.731	78742.73	78675.17	-0.33%	-0.40%	-0.41%	-0.34%	-0.43%
hd	39382.93	38386.08	38447.29	38405.111	38563.81	38389.12	-2.53%	-2.38%	-2.48%	-2.08%	-2.52%
o	45684.05	45376.81	45311.8	45294.376	45361.14	45280.57	-0.67%	-0.81%	-0.85%	-0.71%	-0.88%
oc	103756.8	101929.8	101342.1	102225.8	102580.9	102075.2	-1.76%	-2.33%	-1.48%	-1.13%	-1.62%
s	173169	171809.5	171427.8	171350.9	171662.6	171247.4	-0.79%	-1.01%	-1.05%	-0.87%	-1.11%
sb	48677.7	48456.15	48378.28	48485.784	48530.14	48466.36	-0.46%	-0.62%	-0.39%	-0.30%	-0.43%
t	48416.18	47421.29	46897.29	46847.44	47084.76	46775.11	-2.05%	-3.14%	-3.24%	-2.75%	-3.39%
z	125209.3	122674.3	122079.4	122172.03	122715	122040.6	-2.02%	-2.50%	-2.43%	-1.99%	-2.53%
zm	50931.23	50925.36	50924.12	50923.781	50925.06	50923.52	-0.01%	-0.01%	-0.01%	-0.01%	-0.02%
HLD - Household labour supply											
1	207	206.7394	206.5155	206.48425	205.2552	206.5517	-0.13%	-0.23%	-0.25%	-0.84%	-0.22%
2	640	641.6174	639.6352	639.64428	638.5505	641.2487	0.25%	-0.06%	-0.06%	-0.23%	0.20%
3	3470	3485.259	3469.294	3470.078	3472.217	3482.819	0.44%	-0.02%	0.00%	0.06%	0.37%
4	10348	10367.5	10316.65	10321.03	10359.69	10357.62	0.19%	-0.30%	-0.26%	0.11%	0.09%
5	18551	18505.96	18413.1	18429.56	18536.79	18478.06	-0.24%	-0.74%	-0.65%	-0.08%	-0.39%
6	28978	28713.71	28567.37	28617.132	28819.92	28644.02	-0.91%	-1.42%	-1.25%	-0.55%	-1.15%
7	37653	37164.67	36945.42	37047.923	37348.58	37053.09	-1.30%	-1.88%	-1.61%	-0.81%	-1.59%
8	48300	47423.34	47087.29	47292.96	47712.22	47242.27	-1.82%	-2.51%	-2.08%	-1.22%	-2.19%
9	61274	59971.92	59488.61	59818.402	60460	59714.06	-2.13%	-2.91%	-2.38%	-1.33%	-2.55%
10	101061	99032.82	97958.82	98717.133	100091.8	98621.27	-2.01%	-3.07%	-2.32%	-0.96%	-2.41%

HP -Consumption price index

1	1.160835	1.164208	1.165808	1.1645932	1.164783	1.164431	0.29%	0.43%	0.32%	0.34%	0.31%
2	1.158564	1.162659	1.163689	1.1624754	1.162665	1.162313	0.35%	0.44%	0.34%	0.35%	0.32%
3	1.148448	1.153929	1.153715	1.1525123	1.1527	1.152352	0.48%	0.46%	0.35%	0.37%	0.34%
4	1.143039	1.148166	1.148172	1.1461333	1.146451	1.145861	0.45%	0.45%	0.27%	0.30%	0.25%
5	1.138112	1.143003	1.143174	1.1405835	1.140988	1.140238	0.43%	0.44%	0.22%	0.25%	0.19%
6	1.125859	1.130079	1.130575	1.1272026	1.127729	1.126752	0.37%	0.42%	0.12%	0.17%	0.08%
7	1.117076	1.119374	1.121288	1.1164438	1.117199	1.115798	0.21%	0.38%	-0.06%	0.01%	-0.11%
8	1.107481	1.108215	1.11124	1.1051809	1.106126	1.104373	0.07%	0.34%	-0.21%	-0.12%	-0.28%
9	1.10145	1.101374	1.104955	1.098253	1.099298	1.097359	-0.01%	0.32%	-0.29%	-0.20%	-0.37%
10	1.083802	1.080077	1.086327	1.0768205	1.078302	1.075554	-0.34%	0.23%	-0.64%	-0.51%	-0.76%

HNI - Household net income

1	12646.23	12598.16	12617.51	12616.254	12612.22	12903.08	-0.38%	-0.23%	-0.24%	-0.27%	2.03%
2	15980.43	15837.6	15894.54	15890.901	15880.98	16169.76	-0.89%	-0.54%	-0.56%	-0.62%	1.18%
3	21397.41	21086.82	21173.62	21171.529	21160.17	21426.3	-1.45%	-1.05%	-1.06%	-1.11%	0.13%
4	26924.95	26332.46	26427.36	26434.77	26447.29	26575.88	-2.20%	-1.85%	-1.82%	-1.77%	-1.30%
5	33964.3	33028.84	33118.87	33143.576	33210.76	33190.85	-2.75%	-2.49%	-2.42%	-2.22%	-2.28%
6	41983.06	40584.61	40637.84	40698.788	40826.73	40644.66	-3.33%	-3.20%	-3.06%	-2.75%	-3.19%
7	49606.75	47759.99	47787.91	47892.899	48109.03	47737.28	-3.72%	-3.67%	-3.45%	-3.02%	-3.77%
8	59022.54	56578.11	56545.13	56729.911	57046.78	56459.47	-4.14%	-4.20%	-3.88%	-3.35%	-4.34%
9	71663.95	68517.55	68430.27	68705.549	69244.75	68316.85	-4.39%	-4.51%	-4.13%	-3.38%	-4.67%
10	121536.8	116211	116088	116645.82	118039.9	115870.2	-4.38%	-4.48%	-4.02%	-2.88%	-4.66%

Food

Total	61166.66	59309.69	59395.7	59335.132	59563.55	59341.7	-3.04%	-2.90%	-2.99%	-2.62%	-2.98%
1	2747.536	2735.307	2729.667	2728.3528	2727.832	2777.466	-0.45%	-0.65%	-0.70%	-0.72%	1.09%
2	3364.242	3334.001	3333.56	3331.6342	3330.207	3377.342	-0.90%	-0.91%	-0.97%	-1.01%	0.39%
3	4288.012	4229.362	4231.338	4229.3566	4227.859	4268.509	-1.37%	-1.32%	-1.37%	-1.40%	-0.45%
4	4251.976	4158.91	4168.719	4166.7615	4168.63	4182.449	-2.19%	-1.96%	-2.00%	-1.96%	-1.64%
5	5704.18	5561.172	5566.137	5564.0482	5573.26	5569.254	-2.51%	-2.42%	-2.46%	-2.30%	-2.37%
6	6566.139	6371.492	6372.852	6371.5566	6387.67	6364.163	-2.96%	-2.94%	-2.96%	-2.72%	-3.08%
7	7078.485	6842.618	6846.862	6843.0341	6867.991	6824.727	-3.33%	-3.27%	-3.33%	-2.97%	-3.58%
8	7731.061	7443.653	7448.975	7443.8349	7477.626	7414.946	-3.72%	-3.65%	-3.72%	-3.28%	-4.09%
9	8597.003	8256.776	8265.966	8260.1067	8311.06	8222.672	-3.96%	-3.85%	-3.92%	-3.33%	-4.35%
10	10838.03	10376.4	10431.62	10396.446	10491.41	10340.17	-4.26%	-3.75%	-4.07%	-3.20%	-4.59%

Alc

Total	6075.122	6669.895	5959.12	5948.8328	5985.62	5959.728	9.79%	-1.91%	-2.08%	-1.47%	-1.90%
1	456.222	504.8923	459.0619	458.74817	458.6238	470.5204	10.67%	0.62%	0.55%	0.53%	3.13%
2	525.5059	579.7849	527.394	526.95025	526.6215	537.514	10.33%	0.36%	0.27%	0.21%	2.29%
3	528.3979	584.3266	528.6259	528.24441	527.9562	535.8017	10.58%	0.04%	-0.03%	-0.08%	1.40%
4	573.0704	630.3753	568.4551	568.00494	568.4346	571.6167	10.00%	-0.81%	-0.88%	-0.81%	-0.25%
5	614.985	675.3799	606.027	605.64417	607.3336	606.5986	9.82%	-1.46%	-1.52%	-1.24%	-1.36%
6	593.1431	651.9277	580.2384	580.02935	582.6319	578.8369	9.91%	-2.18%	-2.21%	-1.77%	-2.41%
7	637.3985	696.9444	619.8245	619.20089	623.2725	616.2219	9.34%	-2.76%	-2.85%	-2.22%	-3.32%
8	644.8803	703.6023	623.0406	622.24006	627.5118	617.7498	9.11%	-3.39%	-3.51%	-2.69%	-4.21%
9	670.1504	732.2411	645.0894	644.19709	651.9773	638.5101	9.27%	-3.74%	-3.87%	-2.71%	-4.72%
10	831.3683	910.4201	801.3631	795.57351	811.2571	786.3579	9.51%	-3.61%	-4.31%	-2.42%	-5.41%

Fuel

Total	1269.67	1133.323	1238.738	1239.0422	1238.009	1239.429	-10.74%	-2.44%	-2.41%	-2.49%	-2.38%
1	46.08012	40.86298	44.69461	44.6957	44.69613	44.64331	-11.32%	-3.01%	-3.00%	-3.00%	-3.12%
2	54.40968	48.02598	52.8641	52.868977	52.87257	52.74434	-11.73%	-2.84%	-2.83%	-2.83%	-3.06%
3	75.11979	66.62217	73.00147	73.005503	73.00853	72.92026	-11.31%	-2.82%	-2.81%	-2.81%	-2.93%
4	101.3089	90.51784	98.23938	98.238346	98.23934	98.24552	-10.65%	-3.03%	-3.03%	-3.03%	-3.02%
5	127.7964	114.3707	123.8482	123.8458	123.8562	123.8518	-10.51%	-3.09%	-3.09%	-3.08%	-3.09%
6	141.779	126.7403	137.7235	137.72392	137.7179	137.7262	-10.61%	-2.86%	-2.86%	-2.86%	-2.86%
7	155.4252	139.0011	151.0551	151.05677	151.0445	151.0633	-10.57%	-2.81%	-2.81%	-2.82%	-2.81%
8	160.3144	143.2048	156.5469	156.56018	156.4703	156.6316	-10.67%	-2.35%	-2.34%	-2.40%	-2.30%
9	174.4281	155.7374	171.111	171.13712	170.9035	171.2989	-10.72%	-1.90%	-1.89%	-2.02%	-1.79%
10	233.0081	208.2395	229.6536	229.90993	229.2004	230.3043	-10.63%	-1.44%	-1.33%	-1.63%	-1.16%

Clothing

Total	6400.713	6398.923	6111.013	6095.7347	6152.678	6079.928	-0.03%	-4.53%	-4.76%	-3.88%	-5.01%
1	131.4908	138.4224	132.0375	131.89958	131.8449	137.0899	5.27%	0.42%	0.31%	0.27%	4.26%
2	213.7063	223.1984	213.249	213.00214	212.8193	218.8915	4.44%	-0.21%	-0.33%	-0.42%	2.43%
3	304.2415	314.8486	301.1153	300.83393	300.6214	306.4137	3.49%	-1.03%	-1.12%	-1.19%	0.71%
4	387.6505	396.3147	378.9289	378.55317	378.9118	381.5689	2.24%	-2.25%	-2.35%	-2.25%	-1.57%
5	547.7642	555.9748	530.6048	530.21349	531.9406	531.1892	1.50%	-3.13%	-3.20%	-2.89%	-3.03%
6	613.551	616.2142	587.6614	587.42053	590.4187	586.0471	0.43%	-4.22%	-4.26%	-3.77%	-4.48%
7	708.4074	706.7847	674.1085	673.35288	678.2872	669.7439	-0.23%	-4.84%	-4.95%	-4.25%	-5.46%
8	843.9874	836.4939	797.375	796.28339	803.4726	790.1615	-0.89%	-5.52%	-5.65%	-4.80%	-6.38%
9	1053.469	1040.787	991.6292	990.24151	1002.342	981.3974	-1.20%	-5.87%	-6.00%	-4.85%	-6.84%
10	1596.445	1569.884	1504.303	1493.9341	1522.02	1477.425	-1.66%	-5.77%	-6.42%	-4.66%	-7.46%

Transport

Total	28393.8	27419.92	26903.43	26842.383	27075.54	26771.91	-3.43%	-5.25%	-5.46%	-4.64%	-5.71%
1	443.0082	453.0834	436.298	435.81988	435.6304	453.8226	2.27%	-1.51%	-1.62%	-1.67%	2.44%
2	709.2316	716.9014	696.6759	695.83096	695.2051	715.991	1.08%	-1.77%	-1.89%	-1.98%	0.95%
3	1325.653	1325.191	1296.892	1295.7416	1294.872	1318.556	-0.03%	-2.17%	-2.26%	-2.32%	-0.54%
4	1962.046	1938.571	1901.767	1900.0534	1901.689	1913.806	-1.20%	-3.07%	-3.16%	-3.08%	-2.46%
5	2580.196	2528.644	2480.462	2478.7546	2486.29	2483.012	-2.00%	-3.87%	-3.93%	-3.64%	-3.77%
6	3053.338	2966.026	2906.237	2905.1454	2918.736	2898.919	-2.86%	-4.82%	-4.85%	-4.41%	-5.06%
7	3510.436	3387.748	3322.147	3318.7214	3341.087	3302.359	-3.49%	-5.36%	-5.46%	-4.82%	-5.93%
8	3924.444	3759.515	3686.283	3681.5474	3712.728	3654.988	-4.20%	-6.07%	-6.19%	-5.39%	-6.87%
9	4529.235	4319.1	4234.763	4229.0706	4278.698	4192.789	-4.64%	-6.50%	-6.63%	-5.53%	-7.43%
10	6356.214	6025.139	5941.91	5901.6975	6010.608	5837.67	-5.21%	-6.52%	-7.15%	-5.44%	-8.16%

Other											
Total	101495	98793.83	98222.98	98067.211	98654.23	97946.03	-2.66%	-3.22%	-3.38%	-2.80%	-3.50%
1	3139.71	3160.854	3136.426	3134.549	3133.805	3204.878	0.67%	-0.10%	-0.16%	-0.19%	2.08%
2	4106.815	4113.385	4089.815	4086.8406	4084.637	4157.57	0.16%	-0.41%	-0.49%	-0.54%	1.24%
3	5746.12	5723.283	5693.137	5689.7299	5687.155	5757.161	-0.40%	-0.92%	-0.98%	-1.03%	0.19%
4	7316.732	7230.44	7191.079	7186.4513	7190.868	7223.567	-1.18%	-1.72%	-1.78%	-1.72%	-1.27%
5	8778.214	8624.564	8572.301	8568.0213	8586.904	8578.69	-1.75%	-2.35%	-2.39%	-2.18%	-2.27%
6	10832.71	10576.21	10501.5	10498.635	10534.26	10482.3	-2.37%	-3.06%	-3.08%	-2.76%	-3.23%
7	11456.37	11130.59	11054.79	11046.44	11100.96	11006.51	-2.84%	-3.51%	-3.58%	-3.10%	-3.93%
8	12883.88	12450.92	12364.53	12352.892	12429.44	12287.59	-3.36%	-4.03%	-4.12%	-3.53%	-4.63%
9	15836.88	15254.28	15147.71	15132.823	15262.5	15037.82	-3.68%	-4.35%	-4.45%	-3.63%	-5.05%
10	21397.52	20529.3	20471.69	20370.829	20643.69	20209.94	-4.06%	-4.33%	-4.80%	-3.52%	-5.55%
Sevices											
Total	44037.81	42676.34	42295.26	42208.812	42521.48	42105.41	-3.09%	-3.96%	-4.15%	-3.44%	-4.39%
1	995.5311	1007.264	991.1887	990.51131	990.2428	1015.927	1.18%	-0.44%	-0.50%	-0.53%	2.05%
2	1332.957	1340.144	1322.607	1321.5135	1320.704	1347.532	0.54%	-0.78%	-0.86%	-0.92%	1.09%
3	1897.859	1894.793	1872.583	1871.3179	1870.362	1896.376	-0.16%	-1.33%	-1.40%	-1.45%	-0.08%
4	2775.946	2743.274	2716.021	2714.0825	2715.933	2729.633	-1.18%	-2.16%	-2.23%	-2.16%	-1.67%
5	3298.826	3239.638	3203.988	3202.2061	3210.068	3206.648	-1.79%	-2.87%	-2.93%	-2.69%	-2.79%
6	4017.885	3917.448	3871.561	3870.3895	3884.973	3863.705	-2.50%	-3.64%	-3.67%	-3.31%	-3.84%
7	4992.84	4838.768	4788.763	4784.7848	4810.751	4765.774	-3.09%	-4.09%	-4.17%	-3.65%	-4.55%
8	5889.648	5673.357	5616.6	5610.8155	5648.887	5578.353	-3.67%	-4.64%	-4.73%	-4.09%	-5.29%
9	6544.73	6282.937	6217.556	6210.8454	6269.311	6168.045	-4.00%	-5.00%	-5.10%	-4.21%	-5.76%
10	12291.59	11738.72	11694.39	11632.345	11800.25	11533.42	-4.50%	-4.86%	-5.36%	-4.00%	-6.17%
Durables											
Total	44426.54	42886.06	42980.64	42915.468	43160.72	42890.76	-3.47%	-3.25%	-3.40%	-2.85%	-3.46%
1	1854.84	1850.303	1850.751	1849.6321	1849.189	1891.553	-0.24%	-0.22%	-0.28%	-0.30%	1.98%
2	2146.719	2130.465	2135.333	2133.7646	2132.603	2171.06	-0.76%	-0.53%	-0.60%	-0.66%	1.13%
3	2788.435	2751.845	2759.479	2757.8119	2756.552	2790.807	-1.31%	-1.04%	-1.10%	-1.14%	0.09%
4	3238.779	3171.069	3179.332	3177.2678	3179.238	3193.827	-2.09%	-1.84%	-1.90%	-1.84%	-1.39%
5	3795.015	3693.853	3701.162	3699.2966	3707.526	3703.946	-2.67%	-2.47%	-2.52%	-2.31%	-2.40%
6	4842.311	4683.564	4688.102	4686.8119	4702.861	4679.454	-3.28%	-3.18%	-3.21%	-2.88%	-3.36%
7	5093.97	4902.463	4908.46	4904.7156	4929.15	4886.82	-3.76%	-3.64%	-3.72%	-3.24%	-4.07%
8	5467.446	5233.669	5239.398	5234.4226	5267.163	5206.493	-4.28%	-4.17%	-4.26%	-3.66%	-4.77%
9	6657.749	6352.352	6359.062	6352.7559	6407.678	6312.525	-4.59%	-4.49%	-4.58%	-3.76%	-5.19%
10	8541.276	8116.477	8159.565	8118.9891	8228.761	8054.271	-4.97%	-4.47%	-4.94%	-3.66%	-5.70%

Appendix 6c - Model results for a doubling of current production taxes

		Revenue returning instrument					Percentage changes from baseline				
	Baseline	C taxes	P Labour	Corporation	Income	Lump-sum	C taxes	P Labour	Corporation	Income	Lump-sum
		-0.6285	0.210908	0.3707884	0.918714	1.071928					
Instrument	-										
w	0.909091	0.871009	0.879626	0.8619382	0.856624	0.89684	-4.19%	-3.24%	-5.19%	-5.77%	-1.35%
r	1	0.919505	0.974835	0.9267214	0.96429	0.939172	-8.05%	-2.52%	-7.33%	-3.57%	-6.08%
E	1	0.996961	0.996961	0.9969607	0.996961	0.996961	-0.30%	-0.30%	-0.30%	-0.30%	-0.30%
Q	921786.9	908178.5	910130.4	903001.87	914840.3	924887.2	-1.48%	-1.26%	-2.04%	-0.75%	0.34%
Q P index	1	0.981474	1.021218	0.9767438	0.983453	0.992757	-1.85%	2.12%	-2.33%	-1.65%	-0.72%
Q P t index	1.051586	1.039598	1.079258	1.0349943	1.041327	1.050303	-1.14%	2.63%	-1.58%	-0.98%	-0.12%
C P Index	1.116322	1.114736	1.120635	1.1117775	1.114504	1.115306	-0.14%	0.39%	-0.41%	-0.16%	-0.09%
C	293159.3	282994.1	285481.4	278148.31	287042.4	295153.6	-3.47%	-2.62%	-5.12%	-2.09%	0.68%
G	104994.2	104994.2	104994.2	104994.18	104994.2	104994.2	0.00%	0.00%	0.00%	0.00%	0.00%
I	104426.7	100929	100393.6	100598.14	103542.4	105478.2	-3.35%	-3.86%	-3.67%	-0.85%	1.01%
X	128586.2	128632	128632	128631.96	128632	128632	0.04%	0.04%	0.04%	0.04%	0.04%
M	143322.9	143314.2	143314.2	143314.19	143314.2	143314.2	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%
G exp (£)	277885.3	275301.6	281659.2	274626.01	274973.3	288702.2	-0.93%	1.36%	-1.17%	-1.05%	3.89%
G rev (£)	259782.9	257199.3	263556.9	256523.69	256871	270599.9	-0.99%	1.45%	-1.25%	-1.12%	4.16%
T L D	310481.9	305316.3	304254.8	303430.73	310249.6	310249.6	-1.66%	-2.01%	-2.27%	-0.07%	-0.07%
Prices (raw)											
a	1	0.979058	1.007717	0.9747917	0.986715	0.987867	-2.09%	0.77%	-2.52%	-1.33%	-1.21%
c	1	0.988231	1.026436	0.9846619	0.982879	0.998429	-1.18%	2.64%	-1.53%	-1.71%	-0.16%
d	1	0.968883	0.994462	0.9639254	0.984114	0.977418	-3.11%	-0.55%	-3.61%	-1.59%	-2.26%
e1	1	0.993916	1.034248	0.9900858	0.989606	1.004874	-0.61%	3.42%	-0.99%	-1.04%	0.49%
e2	1	0.935769	1.000217	0.9250216	0.961412	0.956072	-6.42%	0.02%	-7.50%	-3.86%	-4.39%
e3	1	0.977308	1.023335	0.9706897	0.989115	0.991365	-2.27%	2.33%	-2.93%	-1.09%	-0.86%
e4	1	1.106741	1.155915	1.1022109	1.104622	1.120821	10.67%	15.59%	10.22%	10.46%	12.08%
e5	1	0.971992	1.031821	0.9645462	0.977342	0.989249	-2.80%	3.18%	-3.55%	-2.27%	-1.08%
f	1	0.990567	1.024696	0.9873762	0.986672	0.999782	-0.94%	2.47%	-1.26%	-1.33%	-0.02%
g	1	0.968103	1.044668	0.9604434	0.960471	0.988795	-3.19%	4.47%	-3.96%	-3.95%	-1.12%
hd	1	0.945292	1.005879	0.9357299	0.964802	0.964038	-5.47%	0.59%	-6.43%	-3.52%	-3.60%
o	1	0.987846	1.023959	0.9844778	0.983057	0.997515	-1.22%	2.40%	-1.55%	-1.69%	-0.25%
oc	1	0.970161	1.007083	0.9645691	0.980053	0.9815	-2.98%	0.71%	-3.54%	-1.99%	-1.85%
s	1	0.980613	1.013173	0.9764744	0.983273	0.990065	-1.94%	1.32%	-2.35%	-1.67%	-0.99%
sb	1	0.984676	1.024642	0.9808223	0.97982	0.995396	-1.53%	2.46%	-1.92%	-2.02%	-0.46%
t	1	0.990673	1.019353	0.987891	0.989238	0.9986	-0.93%	1.94%	-1.21%	-1.08%	-0.14%
z	1	0.985954	1.026716	0.9820705	0.981204	0.996924	-1.40%	2.67%	-1.79%	-1.88%	-0.31%
zm	1	0.992572	1.015508	0.9902996	0.991399	0.998916	-0.74%	1.55%	-0.97%	-0.86%	-0.11%
QD - Output by sector							C taxes	P Labour	Corporation	Income	Lump-sum
a	8038.752	8413.774	7922.487	7747.9131	7955.292	8207.301	4.67%	-1.45%	-3.62%	-1.04%	2.10%
c	10013.31	9888.433	9786.541	9549.5158	9838.938	10084.74	-1.25%	-2.26%	-4.63%	-1.74%	0.71%
d	77388.42	75976.57	76009.54	75794.701	76937.28	77791.31	-1.82%	-1.78%	-2.06%	-0.58%	0.52%
e1	3828.899	3807.113	3826.66	3827.4198	3826.425	3825.605	-0.57%	-0.06%	-0.04%	-0.06%	-0.09%
e2	11812.04	11834.72	11834.72	11834.722	11834.72	11834.72	0.19%	0.19%	0.19%	0.19%	0.19%
e3	11088.18	10883.39	11070.98	11078.272	11068.73	11060.86	-1.85%	-0.16%	-0.09%	-0.18%	-0.25%
e4	22105.07	21707.14	22051.13	22064.504	22047	22032.57	-1.80%	-0.24%	-0.18%	-0.26%	-0.33%
e5	6980.809	6671.761	6938.35	6948.7111	6935.145	6923.963	-4.43%	-0.61%	-0.46%	-0.65%	-0.81%
f	56290.51	54335.64	55029.1	53971.898	55238.73	56567.5	-3.47%	-2.24%	-4.12%	-1.87%	0.49%
g	79013.71	78676.33	78772.64	78531.58	78824.18	79087.83	-0.43%	-0.31%	-0.61%	-0.24%	0.09%
hd	39382.93	38200.23	38667.61	37967.103	38813.48	39635.3	-3.00%	-1.82%	-3.60%	-1.45%	0.64%
o	45684.05	45287.1	45401.68	45114.73	45463.51	45777.69	-0.87%	-0.62%	-1.25%	-0.48%	0.20%
oc	103756.8	101746.1	101540.5	101536.65	103206.3	104346	-1.94%	-2.14%	-2.14%	-0.53%	0.57%
s	173169	171439.4	171855.4	170606.32	172151.9	173373.6	-1.00%	-0.76%	-1.48%	-0.59%	0.12%
sb	48677.7	48433.94	48405.42	48401.857	48609.59	48748.89	-0.50%	-0.56%	-0.57%	-0.14%	0.15%
t	48416.18	47143.29	47288.9	46299.091	47526.55	48565.23	-2.63%	-2.33%	-4.37%	-1.84%	0.31%
z	125209.3	121983.6	122712.5	120744.83	123536.3	125961	-2.58%	-1.99%	-3.57%	-1.34%	0.60%
zm	50931.23	50930.13	50932.33	50926.832	50933.5	50939.51	0.00%	0.00%	-0.01%	0.00%	0.02%
HLD - Household labour supply											
1	207	206.4172	206.4956	206.04024	204.7852	207.2653	-0.28%	-0.24%	-0.46%	-1.07%	0.13%
2	640	641.1494	639.2917	639.58778	637.7932	642.9107	0.18%	-0.11%	-0.06%	-0.34%	0.45%
3	3470	3484.903	3467.328	3474.3549	3471.064	3491.131	0.43%	-0.08%	0.13%	0.03%	0.61%
4	10348	10369.93	10319.22	10334.074	10376.14	10402.63	0.21%	-0.28%	-0.13%	0.27%	0.53%
5	18551	18508.43	18436.22	18434.649	18599.71	18615.71	-0.23%	-0.62%	-0.63%	0.26%	0.35%
6	28978	28705.53	28643.82	28568.998	28976.54	28996.1	-0.94%	-1.15%	-1.41%	-0.01%	0.06%
7	37653	37146.81	37072.79	36945.608	37603.52	37632.31	-1.34%	-1.54%	-1.88%	-0.13%	-0.05%
8	48300	47383.86	47295.42	47085.623	48117.2	48196.29	-1.90%	-2.08%	-2.51%	-0.38%	-0.21%
9	61274	59910.24	59784.79	59498.479	61062.05	61094.39	-2.23%	-2.43%	-2.90%	-0.35%	-0.29%
10	101061	98958.99	98389.46	98243.312	101200.8	100970.9	-2.08%	-2.64%	-2.79%	0.14%	-0.09%

HP -Consumption price index											
1	1.160835	1.161589	1.163856	1.1617119	1.162445	1.162558	0.06%	0.26%	0.08%	0.14%	0.15%
2	1.158564	1.159884	1.161661	1.1595209	1.160253	1.160365	0.11%	0.27%	0.08%	0.15%	0.16%
3	1.148448	1.150905	1.151614	1.1494922	1.150218	1.150329	0.21%	0.28%	0.09%	0.15%	0.16%
4	1.143039	1.144941	1.146462	1.1428656	1.144096	1.144284	0.17%	0.30%	-0.02%	0.09%	0.11%
5	1.138112	1.139639	1.141715	1.1371436	1.138707	1.138947	0.13%	0.32%	-0.09%	0.05%	0.07%
6	1.125859	1.126651	1.12959	1.1236383	1.125673	1.125985	0.07%	0.33%	-0.20%	-0.02%	0.01%
7	1.117076	1.115876	1.121123	1.1125747	1.115496	1.115945	-0.11%	0.36%	-0.40%	-0.14%	-0.10%
8	1.107481	1.104668	1.111772	1.1010781	1.104732	1.105293	-0.25%	0.39%	-0.58%	-0.25%	-0.20%
9	1.10145	1.097802	1.105862	1.0940336	1.098074	1.098695	-0.33%	0.40%	-0.67%	-0.31%	-0.25%
10	1.083802	1.076374	1.08881	1.0720294	1.077758	1.078639	-0.69%	0.46%	-1.09%	-0.56%	-0.48%
HNI - Household net income											
1	12646.23	12587.14	12624.13	12589.709	12616.9	13456.55	-0.47%	-0.17%	-0.45%	-0.23%	6.41%
2	15980.43	15804.83	15914.32	15812.045	15895.72	16832.41	-1.10%	-0.41%	-1.05%	-0.53%	5.33%
3	21397.41	21018.74	21221.61	21008.869	21202.22	22265.98	-1.77%	-0.82%	-1.82%	-0.91%	4.06%
4	26924.95	26214.4	26530.17	26149.554	26553.37	27579.5	-2.64%	-1.47%	-2.88%	-1.38%	2.43%
5	33964.3	32858.12	33291.04	32722.121	33407.97	34459.89	-3.26%	-1.98%	-3.66%	-1.64%	1.46%
6	41983.06	40355.52	40907.33	40113.721	41149.87	42301.33	-3.88%	-2.56%	-4.45%	-1.98%	0.76%
7	49606.75	47472.29	48145.85	47142.779	48562.07	49769.85	-4.30%	-2.94%	-4.97%	-2.11%	0.33%
8	59022.54	56218.66	57019.37	55768.282	57672.56	59028.67	-4.75%	-3.39%	-5.51%	-2.29%	0.01%
9	71663.95	68068.07	69037.72	67485.25	70105.02	71551.04	-5.02%	-3.66%	-5.83%	-2.18%	-0.16%
10	121536.8	115420	117067.7	114511.73	119649.8	121226.9	-5.03%	-3.68%	-5.78%	-1.55%	-0.25%
Food											
Total	61166.66	59209.5	59902.96	58845.76	60112.6	61441.36	-3.20%	-2.07%	-3.79%	-1.72%	0.45%
1	2747.536	2738.216	2737.515	2729.6218	2734.995	2878.962	-0.34%	-0.36%	-0.65%	-0.46%	4.78%
2	3364.242	3334.942	3345.348	3326.0702	3340.735	3494.638	-0.87%	-0.56%	-1.13%	-0.70%	3.88%
3	4288.012	4227.488	4250.067	4214.0581	4245.134	4409.302	-1.41%	-0.88%	-1.72%	-1.00%	2.83%
4	4251.976	4157.394	4194.338	4145.7382	4193.735	4310.419	-2.22%	-1.36%	-2.50%	-1.37%	1.37%
5	5704.18	5552.999	5605.284	5524.6169	5613.908	5745.344	-2.65%	-1.73%	-3.15%	-1.58%	0.72%
6	6566.139	6359.82	6425.453	6318.3049	6443.834	6577.229	-3.14%	-2.14%	-3.77%	-1.86%	0.17%
7	7078.485	6827.576	6909.974	6778.0013	6936.339	7063.563	-3.54%	-2.38%	-4.25%	-2.01%	-0.21%
8	7731.061	7424.874	7525.17	7364.6612	7560.98	7691.704	-3.96%	-2.66%	-4.74%	-2.20%	-0.51%
9	8597.003	8235.951	8355.3	8168.4624	8412.631	8538.844	-4.20%	-2.81%	-4.98%	-2.14%	-0.68%
10	10838.03	10350.24	10554.51	10276.225	10630.31	10731.35	-4.50%	-2.62%	-5.18%	-1.92%	-0.98%
Alc											
Total	6075.122	6448.963	5957.677	5783.1031	5990.482	6242.491	6.15%	-1.93%	-4.81%	-1.39%	2.75%
1	456.222	495.2037	457.4794	455.60806	456.8815	491.4355	8.54%	0.28%	-0.13%	0.14%	7.72%
2	525.5059	567.4528	525.7624	521.35703	524.7071	560.3129	7.98%	0.05%	-0.79%	-0.15%	6.62%
3	528.3979	569.6727	526.8421	519.97676	525.8996	557.6093	7.81%	-0.29%	-1.59%	-0.47%	5.53%
4	573.0704	612.7472	567.3399	556.29889	567.2022	594.1165	6.92%	-1.00%	-2.93%	-1.02%	3.67%
5	614.985	654.6722	605.3368	590.73291	606.9073	631.0611	6.45%	-1.57%	-3.94%	-1.31%	2.61%
6	593.1431	629.5427	579.938	562.88602	582.8862	604.484	6.14%	-2.23%	-5.10%	-1.73%	1.91%
7	637.3985	672.0773	620.4127	599.21638	624.6877	645.5068	5.44%	-2.66%	-5.99%	-1.99%	1.27%
8	644.8803	676.666	624.2794	599.66226	629.8352	650.3133	4.93%	-3.19%	-7.01%	-2.33%	0.84%
9	670.1504	702.2359	646.4901	618.50464	655.1986	674.5718	4.79%	-3.53%	-7.71%	-2.23%	0.66%
10	831.3683	868.6931	803.7963	758.86012	816.277	833.0797	4.49%	-3.32%	-8.72%	-1.82%	0.21%
Fuel											
Total	1269.67	1166.229	1255.452	1258.9193	1254.379	1250.637	-8.15%	-1.12%	-0.85%	-1.20%	-1.50%
1	46.08012	42.03093	45.36614	45.373593	45.36859	45.12652	-8.79%	-1.55%	-1.53%	-1.54%	-2.07%
2	54.40968	49.44084	53.62237	53.673587	53.63493	53.1121	-9.13%	-1.45%	-1.35%	-1.42%	-2.38%
3	75.11979	68.55152	74.0514	74.128403	74.06254	73.59124	-8.74%	-1.42%	-1.32%	-1.41%	-2.03%
4	101.3089	93.0167	99.73202	99.709165	99.73189	99.68393	-8.19%	-1.56%	-1.58%	-1.56%	-1.60%
5	127.7964	117.4831	125.7555	125.66498	125.7625	125.8053	-8.07%	-1.60%	-1.67%	-1.59%	-1.56%
6	141.779	130.2656	139.7556	139.7969	139.7411	139.5712	-8.12%	-1.43%	-1.40%	-1.44%	-1.56%
7	155.4252	142.8738	153.2683	153.33137	153.2427	153.0586	-8.08%	-1.39%	-1.35%	-1.40%	-1.52%
8	160.3144	147.3646	158.6439	159.06994	158.5274	158.0358	-8.08%	-1.04%	-0.78%	-1.11%	-1.42%
9	174.4281	160.4252	173.1963	174.04714	172.8929	172.1546	-8.03%	-0.71%	-0.22%	-0.88%	-1.30%
10	233.0081	214.7771	232.0603	234.12427	231.4146	230.4976	-7.82%	-0.41%	0.48%	-0.68%	-1.08%
Clothing											
Total	6400.713	6273.876	6171.984	5934.9588	6224.381	6470.184	-1.98%	-3.57%	-7.28%	-2.75%	1.09%
1	131.4908	136.6429	131.6831	130.85973	131.4199	146.777	3.92%	0.15%	-0.48%	-0.05%	11.63%
2	213.7063	220.0897	213.0724	210.61692	212.4838	232.475	2.99%	-0.30%	-1.45%	-0.57%	8.78%
3	304.2415	310.0011	301.3895	296.31143	300.6917	324.274	1.89%	-0.94%	-2.61%	-1.17%	6.58%
4	387.6505	389.4709	380.329	371.08156	380.2135	402.8553	0.47%	-1.89%	-4.27%	-1.92%	3.92%
5	547.7642	546.0588	533.71	518.71488	535.3245	560.2023	-0.31%	-2.57%	-5.30%	-2.27%	2.27%
6	613.551	604.5544	592.534	572.78276	595.953	621.0356	-1.47%	-3.43%	-6.64%	-2.87%	1.22%
7	708.4074	692.8502	680.9542	655.12055	686.1706	711.6037	-2.20%	-3.88%	-7.52%	-3.14%	0.45%
8	843.9874	819.4873	806.9784	773.18707	814.6107	842.7609	-2.90%	-4.39%	-8.39%	-3.48%	-0.15%
9	1053.469	1019.408	1004.554	960.69856	1018.202	1048.568	-3.23%	-4.64%	-8.81%	-3.35%	-0.47%
10	1596.445	1535.312	1526.78	1445.5853	1549.311	1579.631	-3.83%	-4.36%	-9.45%	-2.95%	-1.05%
Transport											
Total	28393.8	27140.48	27289.6	26298.448	27506.57	28532.55	-4.41%	-3.89%	-7.38%	-3.12%	0.49%
1	443.0082	452.0304	439.2547	436.38481	438.3375	491.913	2.04%	-0.85%	-1.50%	-1.05%	11.04%
2	709.2316	713.8357	701.4039	692.96215	699.3802	768.1664	0.65%	-1.10%	-2.29%	-1.39%	8.31%
3	1325.653	1317.568	1305.735	1284.8822	1302.87	1399.613	-0.61%	-1.50%	-3.08%	-1.72%	5.58%
4	1962.046	1924.069	1918.01	1875.6662	1917.481	2020.972	-1.94%	-2.24%	-4.40%	-2.27%	3.00%
5	2580.196	2507.299	2505.911	2440.2388	2512.978	2621.784	-2.83%	-2.88%	-5.42%	-2.61%	1.61%
6	3053.338	2938.616	2942.506	2852.6254	2958.052	3071.988	-3.76%	-3.63%	-6.57%	-3.12%	0.61%
7	3510.436	3353.547	3368.789	3251.2455	3392.501	3508.009	-4.47%	-4.04%	-7.38%	-3.36%	-0.07%
8	3924.444	3718.388	3744.986	3597.8811	3778.184	3900.544	-5.25%	-4.57%	-8.32%	-3.73%	-0.61%
9	4529.235	4269.588	4307.047	4126.5357	4363.192	4488.047	-5.73%	-4.91%	-8.89%	-3.67%	-0.91%
10	6356.214	5945.535	6055.959	5740.0265	6143.598	6261.514	-6.46%	-4.72%	-9.69%	-3.35%	-1.49%

Other											
Total	101495	97956.89	98966.54	96439.491	99506.76	102270.6	-3.49%	-2.49%	-4.98%	-1.96%	0.76%
1	3139.71	3151.605	3136.819	3125.5879	3133.232	3339.76	0.38%	-0.09%	-0.45%	-0.21%	6.37%
2	4106.815	4096.514	4093.271	4063.6282	4086.173	4324.744	-0.25%	-0.33%	-1.05%	-0.50%	5.31%
3	5746.12	5693.302	5703.815	5642.1789	5695.36	5978.639	-0.92%	-0.74%	-1.81%	-0.88%	4.05%
4	7316.732	7182.8	7217.268	7103.0807	7215.846	7492.776	-1.83%	-1.36%	-2.92%	-1.38%	2.41%
5	8778.214	8560.944	8615.363	8450.9889	8632.999	8903.281	-2.48%	-1.86%	-3.73%	-1.65%	1.42%
6	10832.71	10491.88	10571.35	10335.92	10611.92	10907.97	-3.15%	-2.41%	-4.59%	-2.04%	0.69%
7	11456.37	11034.08	11142.15	10855.817	11199.67	11478.73	-3.69%	-2.74%	-5.24%	-2.24%	0.20%
8	12883.88	12335.15	12479.06	12118.099	12560.13	12857.71	-4.26%	-3.14%	-5.94%	-2.51%	-0.20%
9	15836.88	15106.84	15300.52	14828.87	15446.41	15769.5	-4.61%	-3.39%	-6.36%	-2.47%	-0.43%
10	21397.52	20303.78	20706.92	19915.321	20925.02	21217.48	-5.11%	-3.23%	-6.93%	-2.21%	-0.84%
Sevices											
Total	44037.81	42297.92	42722.11	41455.42	43006.72	44234.9	-3.95%	-2.99%	-5.86%	-2.34%	0.45%
1	995.5311	1004.38	992.8662	988.80765	991.5695	1066.51	0.89%	-0.27%	-0.68%	-0.40%	7.13%
2	1332.957	1334.593	1325.867	1314.9611	1323.254	1411.351	0.12%	-0.53%	-1.35%	-0.73%	5.88%
3	1897.859	1884.671	1879.249	1856.3366	1876.104	1981.757	-0.69%	-0.98%	-2.19%	-1.15%	4.42%
4	2775.946	2725.101	2730.47	2682.5992	2729.873	2846.28	-1.83%	-1.64%	-3.36%	-1.66%	2.53%
5	3298.826	3215.258	3226.219	3157.7333	3233.575	3346.505	-2.53%	-2.20%	-4.28%	-1.98%	1.45%
6	4017.885	3885.505	3905.169	3808.7493	3921.807	4043.409	-3.29%	-2.81%	-5.21%	-2.39%	0.64%
7	4992.84	4796.45	4836.3	4699.8493	4863.749	4997.108	-3.93%	-3.14%	-5.87%	-2.59%	0.09%
8	5889.648	5620.222	5680.322	5500.7084	5720.724	5869.226	-4.57%	-3.55%	-6.60%	-2.87%	-0.35%
9	6544.73	6221.079	6293.94	6081.2286	6359.855	6506.038	-4.95%	-3.83%	-7.08%	-2.82%	-0.59%
10	12291.59	11610.66	11851.71	11364.447	11986.21	12166.71	-5.54%	-3.58%	-7.54%	-2.48%	-1.02%
Durables											
Total	44426.54	42597.58	43319.85	42237.322	43545.28	44815.28	-4.12%	-2.49%	-4.93%	-1.98%	0.88%
1	1854.84	1847.96	1852.022	1845.3241	1849.882	1973.084	-0.37%	-0.15%	-0.51%	-0.27%	6.37%
2	2146.719	2125.216	2138.331	2122.693	2134.586	2260.478	-1.00%	-0.39%	-1.12%	-0.57%	5.30%
3	2788.435	2741.857	2766.168	2735.9946	2762.029	2900.743	-1.67%	-0.80%	-1.88%	-0.95%	4.03%
4	3238.779	3155.177	3192.641	3141.6732	3192.006	3315.645	-2.58%	-1.42%	-3.00%	-1.44%	2.37%
5	3795.015	3672.457	3721.889	3650.2172	3729.58	3847.461	-3.23%	-1.93%	-3.82%	-1.72%	1.38%
6	4842.311	4653.52	4721.939	4615.8466	4740.225	4873.673	-3.90%	-2.49%	-4.68%	-2.11%	0.65%
7	5093.97	4867.653	4950.215	4821.8257	4976.01	5101.176	-4.44%	-2.82%	-5.34%	-2.32%	0.14%
8	5467.446	5193.18	5291.158	5136.6997	5325.853	5453.229	-5.02%	-3.22%	-6.05%	-2.59%	-0.26%
9	6657.749	6300.706	6426.96	6227.1227	6488.782	6625.72	-5.36%	-3.47%	-6.47%	-2.54%	-0.48%
10	8541.276	8039.858	8258.525	7939.9251	8346.324	8464.073	-5.87%	-3.31%	-7.04%	-2.28%	-0.90%

Appendix 6d - Model results for a tripling of current production taxes

		Revenue returning instrument					Percentage changes from baseline				
	Baseline	C taxes	P Labour	Corporation	Income	Lump-sum	C taxes	P Labour	Corporation	Income	Lump-sum
		-0.15065	0.336736	0.3489804	0.830358	1.147305					
Instrument	-										
w	0.909091	0.818523	0.854507	0.8144999	0.805027	0.884914	-9.96%	-6.00%	-10.41%	-11.45%	-2.66%
r	1	0.821837	0.953428	0.8469781	0.927995	0.88084	-17.82%	-4.66%	-15.30%	-7.20%	-11.92%
E	1	0.99394	0.99394	0.9939397	0.99394	0.99394	-0.61%	-0.61%	-0.61%	-0.61%	-0.61%
Q	921786.9	887728.7	900060	883885.24	907885.7	928724	-3.69%	-2.36%	-4.11%	-1.51%	0.75%
Q P index	1	0.954734	1.046666	0.9524408	0.966725	0.985176	-4.53%	4.67%	-4.76%	-3.33%	-1.48%
Q P t index	1.051586	1.01983	1.111262	1.0176513	1.030978	1.048608	-3.02%	5.67%	-3.23%	-1.96%	-0.28%
C P Index	1.116322	1.11058	1.125589	1.107158	1.112593	1.114322	-0.51%	0.83%	-0.82%	-0.33%	-0.18%
C	293159.3	267153.4	279048.4	262973.87	280918.3	297686.4	-8.87%	-4.81%	-10.30%	-4.18%	1.54%
G	104994.2	104994.2	104994.2	104994.18	104994.2	104994.2	0.00%	0.00%	0.00%	0.00%	0.00%
I	104426.7	96265.67	96701.99	96601.772	102657.8	106728	-7.82%	-7.40%	-7.49%	-1.69%	2.20%
X	128586.2	128677.5	128677.5	128677.48	128677.5	128677.5	0.07%	0.07%	0.07%	0.07%	0.07%
M	143322.9	143305.5	143305.5	143305.54	143305.5	143305.5	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%
G exp (£)	277885.3	271585.7	286141.9	271272.6	272079.3	300065.4	-2.27%	2.97%	-2.38%	-2.09%	7.98%
G rev (£)	259782.9	253483.3	268039.6	253170.28	253977	281963.1	-2.42%	3.18%	-2.55%	-2.23%	8.54%
T L D	310481.9	297335	298484.4	295880.44	310021.7	310021.7	-4.23%	-3.86%	-4.70%	-0.15%	-0.15%
Prices (raw)											
a	1	0.950257	1.017745	0.9481652	0.972833	0.975332	-4.97%	1.77%	-5.18%	-2.72%	-2.47%
c	1	0.970583	1.057095	0.9689565	0.965848	0.996661	-2.94%	5.71%	-3.10%	-3.42%	-0.33%
d	1	0.931059	0.991008	0.9287865	0.968275	0.955818	-6.89%	-0.90%	-7.12%	-3.17%	-4.42%
e1	1	0.979936	1.071281	0.9781261	0.978126	1.007692	-2.01%	7.13%	-2.19%	-2.19%	0.77%
e2	1	0.856798	1.006256	0.8518331	0.923312	0.913914	-14.32%	0.63%	-14.82%	-7.67%	-8.61%
e3	1	0.942663	1.050675	0.9391345	0.977197	0.982148	-5.73%	5.07%	-6.09%	-2.28%	-1.79%
e4	1	1.201062	1.320241	1.1984153	1.205289	1.237834	20.11%	32.02%	19.84%	20.53%	23.78%
e5	1	0.931415	1.069585	0.9277005	0.954026	0.978209	-6.86%	6.96%	-7.23%	-4.60%	-2.18%
f	1	0.975708	1.052709	0.9741958	0.973254	0.999057	-2.43%	5.27%	-2.58%	-2.67%	-0.09%
g	1	0.92341	1.098119	0.919899	0.921336	0.977454	-7.66%	9.81%	-8.01%	-7.87%	-2.25%
hd	1	0.875903	1.017436	0.8714593	0.929638	0.928994	-12.41%	1.74%	-12.85%	-7.04%	-7.10%
o	1	0.970158	1.051758	0.9686047	0.966182	0.994791	-2.98%	5.18%	-3.14%	-3.38%	-0.52%
oc	1	0.930167	1.017485	0.9274523	0.959642	0.962769	-6.98%	1.75%	-7.25%	-4.04%	-3.72%
s	1	0.95253	1.029753	0.9504457	0.966141	0.979469	-4.75%	2.98%	-4.96%	-3.39%	-2.05%
sb	1	0.962916	1.053805	0.9611504	0.959829	0.990638	-3.71%	5.38%	-3.88%	-4.02%	-0.94%
t	1	0.976257	1.041265	0.9748214	0.978341	0.996587	-2.37%	4.13%	-2.52%	-2.17%	-0.34%
z	1	0.965323	1.057716	0.9635151	0.962442	0.993455	-3.47%	5.77%	-3.65%	-3.76%	-0.65%
zm	1	0.980837	1.032988	0.9796741	0.982678	0.997246	-1.92%	3.30%	-2.03%	-1.73%	-0.28%
QD - Output by sector							C taxes	P Labour	Corporation	Income	Lump-sum
a	8038.752	8372.316	7832.432	7450.0278	7868.509	8392.191	4.15%	-2.57%	-7.32%	-2.12%	4.40%
c	10013.31	9477.407	9600.697	9087.3113	9664.354	10174.03	-5.35%	-4.12%	-9.25%	-3.48%	1.61%
d	77388.42	74080.23	74770.69	74147.328	76485.33	78269.77	-4.27%	-3.38%	-4.19%	-1.17%	1.14%
e1	3828.899	3796.211	3824.082	3824.8648	3823.838	3822.27	-0.85%	-0.13%	-0.11%	-0.13%	-0.17%
e2	11812.04	11857.28	11857.28	11857.284	11857.28	11857.28	0.38%	0.38%	0.38%	0.38%	0.38%
e3	11088.18	10783.03	11050.51	11058.019	11048.16	11033.11	-2.75%	-0.34%	-0.27%	-0.36%	-0.50%
e4	22105.07	21500.85	21991.33	22005.104	21987.03	21959.44	-2.73%	-0.51%	-0.45%	-0.53%	-0.66%
e5	6980.809	6511.228	6891.339	6902.0163	6888.012	6866.625	-6.73%	-1.28%	-1.13%	-1.33%	-1.64%
f	56290.51	51711.67	53946.22	51594.713	54188.67	56922.56	-8.13%	-4.16%	-8.34%	-3.73%	1.12%
g	79013.71	78157.95	78571.74	78042.48	78633.69	79179.36	-1.08%	-0.56%	-1.23%	-0.48%	0.21%
hd	39382.93	36599.66	38070.03	36532.83	38242.34	39941.27	-7.07%	-3.33%	-7.24%	-2.90%	1.42%
o	45684.05	44674.48	45167.15	44537.064	45241.82	45892.07	-2.21%	-1.13%	-2.51%	-0.97%	0.46%
oc	103756.8	99061.19	99520.97	99225.991	102655.4	105047.1	-4.53%	-4.08%	-4.37%	-1.06%	1.24%
s	173169	168750.9	170757.9	168030.54	171134.9	173664.4	-2.55%	-1.39%	-2.97%	-1.17%	0.29%
sb	48677.7	48103.35	48157.71	48115.166	48541.45	48833.82	-1.18%	-1.07%	-1.16%	-0.28%	0.32%
t	48416.18	45022.23	46344.19	44199.766	46644.2	48790.04	-7.01%	-4.28%	-8.71%	-3.66%	0.77%
z	125209.3	117114.1	120591	116201.56	121855.4	126881.9	-6.47%	-3.69%	-7.19%	-2.68%	1.34%
zm	50931.23	50924.87	50934.3	50922.238	50935.72	50948.16	-0.01%	0.01%	-0.02%	0.01%	0.03%
HLD - Household labour supply											
1	207	205.3313	206.0926	205.00758	202.3746	207.5108	-0.81%	-0.44%	-0.96%	-2.23%	0.25%
2	640	641.3452	638.7649	639.22265	635.3427	645.6839	0.21%	-0.19%	-0.12%	-0.73%	0.89%
3	3470	3495.956	3465.152	3479.6524	3470.971	3511.392	0.75%	-0.14%	0.28%	0.03%	1.19%
4	10348	10374.03	10293.44	10322.491	10401.95	10455.27	0.25%	-0.53%	-0.25%	0.52%	1.04%
5	18551	18407.12	18332.2	18317.011	18646.38	18678.15	-0.78%	-1.18%	-1.26%	0.51%	0.69%
6	28978	28266.3	28338.69	28137.76	28973.41	29012.88	-2.46%	-2.21%	-2.90%	-0.02%	0.12%
7	37653	36361.48	36538.84	36193.879	37553.71	37611.25	-3.43%	-2.96%	-3.88%	-0.26%	-0.11%
8	48300	45993.29	46362.39	45781.218	47933.57	48094.11	-4.78%	-4.01%	-5.21%	-0.76%	-0.43%
9	61274	57852.22	58393.79	57582.107	60852.09	60918.16	-5.58%	-4.70%	-6.03%	-0.69%	-0.58%
10	101061	95737.9	95860.94	95222.089	101351.9	100887.3	-5.27%	-5.15%	-5.78%	0.29%	-0.17%

HP -Consumption price index											
1	1.160835	1.162016	1.166999	1.162473	1.163986	1.164229	0.10%	0.53%	0.14%	0.27%	0.29%
2	1.158564	1.160656	1.16488	1.1603609	1.161872	1.162115	0.18%	0.55%	0.16%	0.29%	0.31%
3	1.148448	1.152343	1.154899	1.1504187	1.151916	1.152157	0.34%	0.56%	0.17%	0.30%	0.32%
4	1.143039	1.145273	1.150122	1.1425299	1.145067	1.145475	0.20%	0.62%	-0.04%	0.18%	0.21%
5	1.138112	1.139243	1.145631	1.1359833	1.139207	1.139725	0.10%	0.66%	-0.19%	0.10%	0.14%
6	1.125859	1.125058	1.133747	1.1211882	1.125383	1.126058	-0.07%	0.70%	-0.41%	-0.04%	0.02%
7	1.117076	1.111727	1.125808	1.1077746	1.113793	1.114762	-0.48%	0.78%	-0.83%	-0.29%	-0.21%
8	1.107481	1.098421	1.116874	1.0943219	1.101844	1.103055	-0.82%	0.85%	-1.19%	-0.51%	-0.40%
9	1.10145	1.090456	1.111178	1.0862373	1.094553	1.095892	-1.00%	0.88%	-1.38%	-0.63%	-0.50%
10	1.083802	1.064186	1.095127	1.059768	1.07154	1.073438	-1.81%	1.04%	-2.22%	-1.13%	-0.96%
HNI - Household net income											
1	12646.23	12514.01	12605.37	12529.043	12587.41	14309.32	-1.05%	-0.32%	-0.93%	-0.47%	13.15%
2	15980.43	15587.04	15858.13	15631.192	15810.37	17735.84	-2.46%	-0.77%	-2.19%	-1.06%	10.98%
3	21397.41	20534.31	21072.07	20597.53	21005.71	23195.65	-4.03%	-1.52%	-3.74%	-1.83%	8.40%
4	26924.95	25282.59	26194.05	25341.723	26178.42	28296.03	-6.10%	-2.71%	-5.88%	-2.77%	5.09%
5	33964.3	31395.9	32717.42	31441.912	32847.26	35022.53	-7.56%	-3.67%	-7.43%	-3.29%	3.12%
6	41983.06	38194.6	39989.22	38207.124	40315.07	42692.84	-9.02%	-4.75%	-8.99%	-3.97%	1.69%
7	49606.75	44638.55	46895.74	44638.538	47517.84	50014.68	-10.02%	-5.46%	-10.02%	-4.21%	0.82%
8	59022.54	52493.42	55297.84	52471.178	56327.5	59128.6	-11.06%	-6.31%	-11.10%	-4.57%	0.18%
9	71663.95	63290.15	66773.66	63255.646	68549.89	71550.79	-11.68%	-6.82%	-11.73%	-4.35%	-0.16%
10	121536.8	107322.1	113193.9	107376.04	117743.3	121113.4	-11.70%	-6.86%	-11.65%	-3.12%	-0.35%
Food											
Total	61166.66	56583.26	58817.81	56466.302	59060.26	61794.15	-7.49%	-3.84%	-7.68%	-3.44%	1.03%
1	2747.536	2721.265	2728.371	2711.0884	2722.565	3014.544	-0.96%	-0.70%	-1.33%	-0.91%	9.72%
2	3364.242	3292.795	3328.496	3286.0163	3317.345	3630.553	-2.12%	-1.06%	-2.33%	-1.39%	7.92%
3	4288.012	4143.469	4216.759	4136.7822	4202.389	4537.541	-3.37%	-1.66%	-3.53%	-2.00%	5.82%
4	4251.976	4033.781	4144.182	4035.7105	4135.512	4374.622	-5.13%	-2.54%	-5.09%	-2.74%	2.88%
5	5704.18	5348.536	5519.948	5339.6679	5523.544	5794.187	-6.23%	-3.23%	-6.39%	-3.17%	1.58%
6	6566.139	6080.243	6304.356	6064.6221	6321.799	6596.551	-7.40%	-3.99%	-7.64%	-3.72%	0.46%
7	7078.485	6488.849	6765.442	6470.9137	6794.672	7057.19	-8.33%	-4.42%	-8.58%	-4.01%	-0.30%
8	7731.061	7012.267	7348.585	6990.6538	7391.764	7661.458	-9.30%	-4.95%	-9.58%	-4.39%	-0.90%
9	8597.003	7752.095	8147.595	7730.753	8229.039	8490.667	-9.83%	-5.23%	-10.08%	-4.28%	-1.24%
10	10838.03	9709.961	10314.08	9700.0937	10421.63	10636.83	-10.41%	-4.83%	-10.50%	-3.84%	-1.86%
Alc											
Total	6075.122	6406.332	5866.448	5484.044	5902.525	6426.207	5.45%	-3.43%	-9.73%	-2.84%	5.78%
1	456.222	516.4757	458.858	454.73794	457.4726	528.8358	13.21%	0.58%	-0.33%	0.27%	15.92%
2	525.5059	587.1559	526.3602	516.61023	523.7946	597.4987	11.73%	0.16%	-1.69%	-0.33%	13.70%
3	528.3979	585.056	525.9851	510.69668	523.2255	589.0125	10.72%	-0.46%	-3.35%	-0.98%	11.47%
4	573.0704	620.0788	563.0363	538.44679	561.0524	616.9548	8.20%	-1.75%	-6.04%	-2.10%	7.66%
5	614.985	655.6556	597.8213	565.3516	598.477	648.7184	6.61%	-2.79%	-8.07%	-2.68%	5.49%
6	593.1431	623.6335	569.4944	531.70157	572.2895	617.1279	5.14%	-3.99%	-10.36%	-3.52%	4.04%
7	637.3985	658.7416	606.9094	560.21337	611.6369	654.8489	3.35%	-4.78%	-12.11%	-4.04%	2.74%
8	644.8803	655.8822	607.8085	553.84875	614.4763	656.8972	1.71%	-5.75%	-14.12%	-4.71%	1.86%
9	670.1504	676.0271	627.5404	566.38798	639.8434	680.1558	0.88%	-6.36%	-15.48%	-4.52%	1.49%
10	831.3683	827.6253	782.6343	686.04906	800.2565	836.1572	-0.45%	-5.86%	-17.48%	-3.74%	0.58%
Fuel											
Total	1269.67	1112.494	1239.71	1243.2839	1238.597	1231.439	-12.38%	-2.36%	-2.08%	-2.45%	-3.01%
1	46.08012	39.65925	44.67507	44.687782	44.67967	44.03724	-13.93%	-3.05%	-3.02%	-3.04%	-4.43%
2	54.40968	46.64398	52.85285	52.950679	52.88009	51.69605	-14.27%	-2.86%	-2.68%	-2.81%	-4.99%
3	75.11979	64.89894	72.99729	73.127362	73.02425	71.98901	-13.61%	-2.83%	-2.65%	-2.79%	-4.17%
4	101.3089	88.2475	98.1784	98.031799	98.17124	98.07671	-12.89%	-3.09%	-3.23%	-3.10%	-3.19%
5	127.7964	111.4867	123.7311	123.35569	123.7363	123.876	-12.76%	-3.18%	-3.47%	-3.18%	-3.07%
6	141.779	123.8426	137.6689	137.46414	137.6696	137.4288	-12.65%	-2.90%	-3.04%	-2.90%	-3.07%
7	155.4252	135.9071	151.0018	150.71891	151.001	150.7595	-12.56%	-2.85%	-3.03%	-2.85%	-3.00%
8	160.3144	140.7497	156.7061	157.03433	156.6148	155.7911	-12.20%	-2.25%	-2.05%	-2.31%	-2.82%
9	174.4281	153.8716	171.5214	172.57537	171.1954	169.8806	-11.79%	-1.67%	-1.06%	-1.85%	-2.61%
10	233.0081	207.1872	230.3776	233.33784	229.6246	227.9042	-11.08%	-1.13%	0.14%	-1.45%	-2.19%
Clothing											
Total	6400.713	5860.903	5984.192	5470.8067	6047.849	6557.529	-8.43%	-6.51%	-14.53%	-5.51%	2.45%
1	131.4908	138.8177	131.9374	130.12935	131.3289	163.2825	5.57%	0.34%	-1.04%	-0.12%	24.18%
2	213.7063	220.9216	212.6517	207.23949	211.2254	252.7463	3.38%	-0.49%	-3.03%	-1.16%	18.27%
3	304.2415	306.6461	299.1201	287.88076	297.0874	345.9882	0.79%	-1.68%	-5.38%	-2.35%	13.72%
4	387.6505	377.4192	374.3384	353.90496	372.6852	419.5611	-2.64%	-3.43%	-8.71%	-3.86%	8.23%
5	547.7642	522.8094	522.1074	489.04702	522.7768	574.2591	-4.56%	-4.68%	-10.72%	-4.56%	4.84%
6	613.551	569.0405	575.138	531.77739	578.3533	630.0787	-7.25%	-6.26%	-13.33%	-5.74%	2.69%
7	708.4074	644.8624	658.2862	601.91958	664.0075	716.4224	-8.97%	-7.08%	-15.03%	-6.27%	1.13%
8	843.9874	754.2287	776.3781	702.99131	785.4624	843.3334	-10.64%	-8.01%	-16.71%	-6.93%	-0.08%
9	1053.469	933.1587	964.0206	868.98371	983.1476	1045.835	-11.42%	-8.49%	-17.51%	-6.68%	-0.72%
10	1596.445	1392.999	1470.214	1296.9332	1501.775	1566.022	-12.74%	-7.91%	-18.76%	-5.93%	-1.91%
Transport											
Total	28393.8	25046.65	26365.75	24221.982	26626.65	28745.77	-11.79%	-7.14%	-14.69%	-6.22%	1.24%
1	443.0082	452.6831	435.8233	429.55552	433.7138	544.6793	2.18%	-1.62%	-3.04%	-2.10%	22.95%
2	709.2316	705.0087	694.4689	675.95476	689.5892	831.8779	-0.60%	-2.08%	-4.69%	-2.77%	17.29%
3	1325.653	1284.166	1288.498	1242.5139	1280.184	1479.856	-3.13%	-2.80%	-6.27%	-3.43%	11.63%
4	1962.046	1842.44	1880.528	1787.1833	1872.984	2086.353	-6.10%	-4.15%	-8.91%	-4.54%	6.34%
5	2580.196	2370.211	2443.016	2298.5413	2445.939	2670.309	-8.14%	-5.32%	-10.92%	-5.20%	3.49%
6	3053.338	2738.836	2849.015	2651.977	2863.6	3097.803	-10.30%	-6.69%	-13.14%	-6.21%	1.46%
7	3510.436	3092.426	3249.922	2993.7251	3275.875	3513.23	-11.91%	-7.42%	-14.72%	-6.68%	0.08%
8	3924.444	3386.967	3594.66	3275.5973	3634.086	3884.918	-13.70%	-8.40%	-16.53%	-7.40%	-1.01%
9	4529.235	3859.248	4120.913	3730.4833	4199.39	4456.377	-14.79%	-9.02%	-17.64%	-7.28%	-1.61%
10	6356.214	5314.664	5808.902	5136.4506	5931.292	6180.364	-16.39%	-8.61%	-19.19%	-6.69%	-2.77%

Other											
Total	101495	92521.51	96859.17	91311.005	97508.63	103228.9	-8.84%	-4.57%	-10.03%	-3.93%	1.71%
1	3139.71	3146.506	3134.905	3110.2465	3126.616	3550.159	0.22%	-0.15%	-0.94%	-0.42%	13.07%
2	4106.815	4057.421	4082.446	4017.0118	4065.242	4555.682	-1.20%	-0.59%	-2.19%	-1.01%	10.93%
3	5746.12	5586.479	5668.735	5531.8225	5644.065	6227.325	-2.78%	-1.35%	-3.73%	-1.78%	8.37%
4	7316.732	6954.173	7134.193	6880.1922	7113.765	7685.266	-4.96%	-2.49%	-5.97%	-2.77%	5.04%
5	8778.214	8208.607	8478.935	8113.4707	8486.281	9045.166	-6.49%	-3.41%	-7.57%	-3.33%	3.04%
6	10832.71	9957.579	10351.88	9829.237	10390.27	11001.44	-8.08%	-4.44%	-9.26%	-4.08%	1.56%
7	11456.37	10386.51	10879.06	10246.349	10942.58	11519.01	-9.34%	-5.04%	-10.56%	-4.48%	0.55%
8	12883.88	11508.44	12139.78	11344.745	12237.01	12850.81	-10.68%	-5.78%	-11.95%	-5.02%	-0.26%
9	15836.88	14017.31	14850.21	13813.211	15056.2	15725.49	-11.49%	-6.23%	-12.78%	-4.93%	-0.70%
10	21397.52	18698.49	20139.04	18424.719	20446.59	21068.57	-12.61%	-5.88%	-13.89%	-4.44%	-1.54%
Sevices											
Total	44037.81	39592.26	41623.73	38860.659	41975.8	44518.33	-10.09%	-5.48%	-11.76%	-4.68%	1.09%
1	995.5311	1004.382	990.5929	981.6989	987.6021	1141.652	0.89%	-0.50%	-1.39%	-0.80%	14.68%
2	1332.957	1322.3	1319.838	1295.8209	1313.519	1494.898	-0.80%	-0.98%	-2.79%	-1.46%	12.15%
3	1897.859	1847.277	1863.441	1812.6931	1854.286	2071.936	-2.67%	-1.81%	-4.49%	-2.30%	9.17%
4	2775.946	2630.751	2692.096	2585.9753	2683.547	2923.62	-5.23%	-3.02%	-6.84%	-3.33%	5.32%
5	3298.826	3070.545	3165.011	3013.3871	3168.065	3401.267	-6.92%	-4.06%	-8.65%	-3.96%	3.11%
6	4017.885	3668.828	3810.225	3597.2115	3825.915	4076.482	-8.69%	-5.17%	-10.47%	-4.78%	1.46%
7	4992.84	4488.87	4704.961	4404.9361	4735.174	5010.062	-10.09%	-5.77%	-11.77%	-5.16%	0.34%
8	5889.648	5209.453	5504.733	5111.2122	5553.021	5858.611	-11.55%	-6.54%	-13.22%	-5.72%	-0.53%
9	6544.73	5731.357	6083.367	5618.3632	6176.099	6478.176	-12.43%	-7.05%	-14.15%	-5.63%	-1.02%
10	12291.59	10618.49	11489.47	10439.361	11678.57	12061.63	-13.61%	-6.53%	-15.07%	-4.99%	-1.87%
Durables											
Total	44426.54	40122.88	42395.11	40019.598	42661.4	45286.84	-9.69%	-4.57%	-9.92%	-3.97%	1.94%
1	1854.84	1837.237	1849.813	1835.1169	1844.872	2097.461	-0.95%	-0.27%	-1.06%	-0.54%	13.08%
2	2146.719	2095.963	2131.412	2096.9152	2122.341	2381.058	-2.36%	-0.71%	-2.32%	-1.14%	10.92%
3	2788.435	2678.752	2747.495	2680.516	2735.425	3020.919	-3.93%	-1.47%	-3.87%	-1.90%	8.34%
4	3238.779	3041.213	3153.905	3040.6132	3144.792	3399.825	-6.10%	-2.62%	-6.12%	-2.90%	4.97%
5	3795.015	3505.289	3660.414	3501.1911	3663.615	3907.234	-7.63%	-3.55%	-7.74%	-3.46%	2.96%
6	4842.311	4396.208	4620.642	4385.3192	4637.932	4913.262	-9.21%	-4.58%	-9.44%	-4.22%	1.47%
7	5093.97	4560.333	4829.628	4546.1887	4858.093	5116.47	-10.48%	-5.19%	-10.75%	-4.63%	0.44%
8	5467.446	4821.858	5143.201	4803.3359	5184.782	5447.332	-11.81%	-5.93%	-12.15%	-5.17%	-0.37%
9	6657.749	5818.298	6232.983	5794.0341	6320.213	6603.696	-12.61%	-6.38%	-12.97%	-5.07%	-0.81%
10	8541.276	7367.723	8025.622	7336.3676	8149.336	8399.582	-13.74%	-6.04%	-14.11%	-4.59%	-1.66%

Chapter 7 - Conclusions

The crux of the double dividend hypothesis is that imposing a tax on an environmental bad and using the revenue gained to reduce other forms of taxation has two beneficial aspects. Firstly the environmental tax means that environmental quality is improved and secondly, the reduction in distortionary taxation increases the efficiency of the economy as a whole.

Although the concept can be traced back to Sandmo (1973), the 1990's saw a large body of literature emerge. To a large extent this literature was spawned by the assertion made in Pearce (1991) that the question of the existence of a double dividend was of crucial importance in addressing the issue of carbon taxation in the context of global warming. However, virtually all of this subsequent work ignores distributional issues. It is the contention here that distributional issues are of vital importance in a social and political context when considering tax reform in reality and it is this matter that this thesis attempts to address.

To recap, Chapter 1 presented an in-depth literature review of the existing double dividend literature. The 'double dividend' was defined, formally, in section 1.2.1 with particular reference to the strong and weak forms as defined by Goulder (1995b). The strong form of the double-dividend hypothesis refers to the effect of revenue-neutral tax reform being such that the tax-reform process in itself is desirable[1] - the economy is 'better off' even if the, presumably beneficial, environmental effects are ignored. The existence of the strong form of the double dividend, the idea that revenue-neutral environmental taxes are desirable in themselves, is the 'holy-grail' of environmental tax reform as it means that the magnitude of environmental effects need not be considered as the tax switch, from economic 'goods' to economic 'bads' is in itself desirable. This is the view taken by the proponents of ecological tax reform, for example von Weizsaker (1991).

The weak form of the double dividend is simply that the tax shift causes the efficiency of the rest of the tax system to be improved. The tax shift in itself is undesirable but revenue-neutrality is found to be preferable to revenue retention or returning revenue through lump-sum transfers. An important point is that lump-sum transfers are considered non-distortionary by classical theory and the argument in favour of the weak form of the double dividend is that although such revenue neutral tax reform may lead to an efficiency loss, there is a gain from the reduction of distortionary taxation that would not exist were the revenue retained or redistributed in a lump-sum fashion. The question of the distortionary properties of lump-sum transfers is one which is returned to below.

A key point in this section, made by Schöb (1995), is that the redistribution of revenue through the lowering on non-environmental taxes will in itself have an environmental effect. This effect may either reinforce or diminish the effect of the environmental tax and will depend on the nature of the complementarity and substitutability relationships between goods. This is an issue that is kept to the forefront throughout the reminder of this work.

Section 1.3 looks at the academic issues present in the existing literature, primarily the distinction between theoretical and empirical analysis. The issue is that the theoretical literature tends to deal with an arbitrary unspecified pollutant whilst the empirical literature, almost in its entirety, deals with carbon taxation. Indeed this distinction is carried forward in this work. It is interesting to note that the bulk of the theoretical literature finds that the double dividend hypothesis does not exist in it's strong form and may not exist in its weak form. The results from the empirical literature are more mixed and a majority finds that the weak form of the second dividend holds. This section also briefly outlines the paper, Bovenberg and de Mooij (1994b) that becomes the basis for Chapter 2.

The bulk of the first chapter is taken up by section 1.4 which produces a framework for categorising the double dividend literature in a policy context. This is done for reasons of expositional clarity and goes some way to allowing differences in the literature to be contextualised. Once this policy framework is in place the section examines the available literature in each of the policy categories.

Section 1.5 examines the choice of revenue recycling instrument. The most common in the literature is income or labour taxes but close inspection suggests that other taxes may also be appropriate. It is difficult or impossible to analyse non-income taxes as a revenue recycling instrument in a theoretical or partial equilibrium framework so the use of these alternative instruments is held over to the empirical general equilibrium model that forms chapters 4, 5 and 6.

Finally in this first chapter, the measurement of desirability used to analyse the double dividend is considered in section 1.6. The use of differing measurements of desirability, primarily employment and welfare, by different authors is judged to complicate the digestion of the existing literature and must be kept in mind, where possible.

This first chapter serves to clarify the methodological approaches that are used in the remainder of the thesis. It is obvious, from an examination of Chapter 1, that both a theoretical and an empirical approach must be undertaken to place the thesis firmly in the context of the existing literature. It is this move from (relatively) simplistic theoretical models to complex empirical analysis that forms the methodological arc of this work.

Chapter 2 extends the theoretical model of Bovenberg and de Mooij (1994b) to encompass differentiated households. This extended model is able to reproduce their results but allows an initial exploration of the distributional issues arising from the double dividend hypothesis.

The basic Bovenberg and de Mooij critique of the double dividend hypothesis is that a revenue neutral change in an environmental tax will cause a fall in employment in the presence of distortionary labour market taxation. The reasoning is as follows: the rise in the environmental tax causes an erosion of the environmental tax base which means that the reduced rate of labour taxation is unable to fully compensate for the adverse effects of the increased environmental tax. This causes a fall in the real (after tax) wage which in turn causes a fall in employment. However, the situation, using such a distortionary tax as a revenue recycling instrument, will be preferable to lump-sum transfers - the weak form of the double dividend holds.

When households are differentiated by income, then sensible assumptions about the differences in wage elasticity of supply between households coupled with similar assumptions about the substitutability of dirty and clean goods mean that lower income households face a smaller relative change in employment. The employment effect is progressive as lower income households lose proportionately less.

Turning to welfare, the situation is unclear as relative changes in welfare depend on the households environmental valuation. It is not clear that how the environmental valuation of households changes as one moves up through the income distribution. It may be surmised that higher income households are likely to value the environment more , but this ignores any local or geographically based pollution effects. It is clear that environmental valuation and hence relative welfare changes will depend on the nature of the pollutant concerned.

The next stage is to examine a relatively simplistic empirical model that allows the need for environmental valuation measures to be avoided. This forms the reasoning behind chapter 3. The model used in this chapter is a simple partial equilibrium model, dealing with only the consumption sector of the economy. This model, which is an extension of Schob (1995), to (again) allow for differentiated households, uses the Almost Ideal Demand (AID) system of Pashardes (1993). The AID system is calibrated to reflect the budget shares of 7 consumption goods for 10 households each representing a decile of the income distribution. One of the seven goods, Fuel, is deemed as the pollutant or 'dirty' good and the tax rate upon it is increased. A revenue neutral change is achieved by reducing the tax rate on each of the other goods, or tax rates overall in terms of VAT.

A measure, the marginal social cost of public funds, is defined that allows the double dividend issue to be analysed in terms of the direct impact, the environmental impact and the distributional impact. The initial theoretical section shows that the environmental dividend may not necessarily be positive. This would be due to the complementarity and substitutability relationships between goods, causing a rise in consumption of the 'dirty' good when the price of clean goods falls (due to the tax rate fall).

The empirical section shows that the environmental dividend is always positive, but, in line with the theory, shows that the size of this environmental improvement is very strongly dependant on the revenue recycling instrument chosen. The strong form of the second dividend exists only when the externality tax revenue is used to reduce the tax rate on Alcohol and Tobacco. However, the weak form of the second dividend holds in all cases.

Turning to distributional issues, lower income households face a direct welfare loss under all alternate tax shift options and thus require a positive environmental valuation in order to be better off. By calculating critical levels of marginal environmental valuation for all households such that they gain, in terms of welfare, when the tax shifts are imposed, the final section of the chapter posits the tentative result that, if environmental valuation, generally, is high, equity may be improved. In other words, if there is a strong environmental valuation in the economy, the revenue-neutral tax change may be progressive in that lower income households gain proportionately more.

As detailed above, the model in this chapter, is a partial equilibrium one and does not take into account employment effects. The next stage in the methodology is the construction of an Applied or Computable General Equilibrium Model[2], that encompasses the entire economy. This model is highly complex in nature and its exposition and results form the remainder of this work.

Chapter 4 details the theoretical background to the CGE model. The focus of the model is, in line with the existing empirical literature, on energy taxation. The model draws heavily from Ballard et.al. (1985) but contains features designed to focus on issues specific to the distributional implications of the double dividend with regard to energy taxation.

The household sector is modelled as 10 separate households each maximising a 3 stage constant elasticity of substitution utility function. In the first stage - a leisure-work trade off - households determine their labour supply. In addition to labour income they receive payment as the owners of the capital in the economy and benefit from transfer payments from government. Once a household's effort is determined, a second stage of the utility function distributes the return from this effort between consumption and saving. The level of saving determines the level of investment in the model. Finally, consumption expenditure is divided, in fixed proportions, between durables and non-durables and non-durable demand is determined by an AID system.

The production side of the model uses an intermediate demand matrix to determine intermediate inputs but it's novel feature is the direct inclusion of energy, along with labour and capital, as a factor of production. Constant-elasticity production functions for each of the 18 production sectors allow energy to be substituted for labour and capital when energy prices change. Each of the 18 sectors is represented by a single competitive firm operating under constant returns to scale and making zero profits.

The government sector is modelled as having fixed expenditure in terms of quantity (but not price), as collecting taxes on income, consumption, produced goods and from producers on labour employed and paying transfer payments to households. The inclusion of transfer payments allows lump-sum redistribution of energy tax revenue to be examined.

The data and calibration procedures used for the model are detailed in Chapter 6. Input-Output tables (1990) for the UK economy are used to calibrate the non-household sectors. Data from Economic Trends is used for the household sector and is matched to the Input-Output data.

The two trade elasticities (export and import) and the uncompensated wage elasticity of labour supply and the savings elasticity are not determined by the calibration process and are determined from external empirical estimates. Sensitivity analysis is performed to determine the effect of changes in these parameters on the model results. The model is not sensitive to the trade elasticities and whilst there is more sensitivity to the two household elasticities, the central cases chosen, of each, give sensible results.

The results of the model are explained in Chapter 7. Energy taxes on consumption and production are examined separately and in each case there are 5 possible revenue returning instruments - Consumption taxes (excluding the energy consumption good - Fuel), taxes on producer labour demand (equivalent to employer's National Insurance contributions), corporation tax (levied on profits i.e. the return to capital), household income taxation and, lastly, an increase in transfer payments (equivalent to a lump-sum transfer).

The results for the energy consumption tax are in line with those of the literature. The weak form of the double dividend hypothesis is found to hold in that all the tax- based revenue recycling instruments were preferable to lump-sum transfers in terms of the effect on output.

With an energy tax on producer prices the results were in conflict with the literature. It was found that the double dividend did not exist in any form and that lump-sum transfer was preferable as the revenue recycling instrument. The reason for this is that the significant revenue raised from the energy tax, when redistributed to households in a lump-sum fashion causes a substantial increase in consumption and thus output. This result is driven by the inclusion of transfer payments as a form of household income.

This result may be somewhat mitigated by the lack of involuntary unemployment in the model. As detailed in section 4.9.3, the existing theoretical papers that include involuntary unemployment tend to be more favourable to the existence of a double dividend. Involuntary unemployment was not included due to the complexity of such a model in a general equilibrium framework. It would be interesting to see if these theoretical results were backed up in an empirical context but this is beyond the scope here.

The key focus here has been distributional issues, and the household results of the model suggest that fears that revenue-neutral environmental tax reform will have a regressive effect are unfounded. All changes to the income distribution in the model's results are progressive in nature, regardless of the revenue-recycling instrument used. The fact that the income of lower income households is comprised of a larger relative share of transfer payments compared with higher income households, means that lower income households are less exposed to changes in wages and the interest rate.

The three models that form this thesis raise an interesting methodological dilemma. It is clear that the more complicated and the more empirical the model, the more it can capture of reality but the less it's results can be understood intuitively (and the harder it is to work with). In addition the more complicated the model the greater the sensitivity of its results to the assumptions made.

As an example, consider the DICE model of Nordhaus (1993) that specifies the link between emissions and climate, and then, climate and the economy. Environmental scientists cannot specify these relationships well in the short term. Indeed weather forecasters fail to accurately predict the situation a week ahead, so how can one expect to model not just climate but the effect of emissions and concentrations of pollutants over a period of decades.

In the context of this work, a potential weakness of the general equilibrium model presented may be the specification of energy as a direct, substitutable input into production. But this is certainly preferable to the simple alternative of a fixed intermediate use coefficient. The other alternative of somehow measuring technical change in production with regard to incentives offered by a rise in the cost of energy is akin to fortune telling and no more likely to produce an accurate forecast.

Thus, there is a trade off to be faced between analytical complexity on one hand and intuition and practicality on the other. It is the contention of the author that such a balance has been struck in this work.

Notes:

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[1]Section 1.6 deals with the notion of 'desirability' - a complicated issue in itself.
[2]The two terms appear to be interchangeable.

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